28th Annual Conference of the Australasian Association for Engineering Education (AAEE 2017)

ORDER OF PROCEEDINGS

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Australasian Association for Engineering Education

MACQUARIE University

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WELCOME TO AAEE 2017

28TH AUSTRALASIAN ASSOCIATION FOR ENGINEERING EDUCATION (AAEE) ANNUAL CONFERENCE

WELCOME MESSAGE FROM THE GENERAL CHAIR OF AAEE 2017, PROFESSOR GRAHAM TOWN

On behalf of the Organising Committee, and Macquarie University's School of Engineering, it is with great pleasure that I welcome you to the 28th Annual Conference of the Australasian Association for Engineering Education.

Engineering is a discipline for the 21st century, combining a range of technical competencies and practical skills with a systems approach to problem solving that enables engineers to shape not only technology, but also society.

The theme of this year's conference is "Integrated Engineering". It refers not only to the combination of theory and practice characteristic of engineering training, and encompasses more than the well-balanced set of technical skills and professional attributes expected in modern engineering graduates. The theme also refers to the need to train engineers who are willing and able to share responsibility for guiding the world in which they live through the major challenges facing society in the 21st century.

Engineering educators have an important role to play in ensuring that engineers become more representative of, and more engaged with, the diverse societies of which we are part - the influence of the role models we provide and the patterns of behaviour we encourage in our students continues long after their graduation.

I trust that this year's AAEE conference will again provide a great forum for sharing ideas and provoking actions so that we, as engineering educators, can ensure graduate engineers are well integrated, in every sense of the word.

PROFESSOR GRAHAM TOWN

General Chair – AAEE 2017

AAEE 2017

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WELCOME

WELCOME FROM THE PROGRAM CHAIRS OF AAEE 2017

Greetings.

This year's conference is an exciting event for us as Macquarie University is hosting this conference for the first time in the 28 years of AAEE history. Macquarie Engineering has experienced an accelerating growth in recent years and to continue its growth in major engineering fields, the School of Engineering was launched recently. We would like to express sincere gratitude to the Faculty of Science and Engineering and the School of Engineering for continuous support since the beginning of this journey.

143 full papers are to be presented at this year's conference in 27 parallel sessions in addition to 13 workshops, 3 keynote lectures, one special guest lecture and one panel discussion. All papers are varied on a range topics based on the five sub-themes (C1, C2, C3, C4 and C5) and three focus sessions (S1, S2 and S3).

Thanks to the Program committee for reviewing more than 200 abstracts and proposals. 14 abstracts were rejected at the initial stage, and 5 were rejected at full paper stage. About 20 papers were withdrawn. Thanks to the Technical Program Committee for providing 283 reviews on about 150 full papers. Thanks to all the authors, who put up with us and 4000 emails through Easychair.

All keynote lectures are very well aligned with the conference theme. And we are sure the panel discussion on "Directions for Engineering Education: the Engineers of 2035" will excite us all.

We would like to thank all the session chairs and focus session facilitators for their time and effort in planning and delivering their respective sessions. We would like to express our gratitude to the keynote speakers for taking valuable time off from their busy schedule and attending this conference to share their valuable insights.

We hope the conference will be a memorable one and we look forward to meeting you all at the AAEE 2017 at Novotel Manly in Sydney.

Sincerely,

DR NAZMUL HUDA (PROGRAM CHAIR)

DR DAVID INGLIS (TECHNICAL CHAIR)

DR NICHOLAS TSE (PROGRAM CO-CHAIR)

AAEE Conference 2017
School of Engineering, Macquarie University

Integrative practice in the making of a 21st century graduate

LINDIE CLARK – Academic & Programs Director, Professional and Community Engagement, Macquarie University

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Universities, graduates, industry and communities face complex challenges and opportunities in a fast-paced, disruptive, globalized world. Increasingly precarious employment futures, profound digital transformation, cultural and political fragmentation, and seemingly intractable environmental and social challenges constitute the dynamic landscape that our students have to negotiate both during and beyond their time at university. For us as educators, however, the key challenge we face in such circumstances remains the age-old one: how best can we support students to develop the capabilities that will enable them to lead meaningful, rewarding and socially productive lives? While the challenge remains the same, the means through which we address it requires a fundamental rethink. In this Keynote Address I argue that a commitment to integrative practices – the underlying theme of this 28th conference – must be at the heart of our collective response.

In what sense "integration"? There are a number of dimensions to consider. Universities operate on tripartite missions: research, teaching, and public service (Furco 2010; Sachs & Clark 2017). Ramley (2014, p. 9) makes the case for the power of engagement – across and between universities and communities – as 'a strategy for linking scholarship and learning to the improvement of life in the community'. In other words, university-community engagement is an integrative force that can unite the three dimensions of a university's mission and link them to a common purpose: addressing the multifarious wicked problems that our communities confront. Doing this, Ramley argues, implies a radical change in the way in which (most) universities work: it requires higher education institutions, students and communities to forge boundary-spanning relationships and work together in partnership. For us as educators, this in turn throws up multiple challenges for our curricular and pedagogical strategies: How best can we (co-)create rich learning experiences that enable our students to develop both disciplinary depth and the ability to work effectively across disciplinary and sectoral boundaries? How best can we enable and support our students to engage with, value and integrate different knowledges; to draw on different perspectives and modalities; and to work effectively with others to collectively define and address complex problems and harness opportunities? University-community engagement – as both a strategy for advancing our raison d'etre as higher education institutions and as an engine of pedagogical change – is thus the first pillar of integrative practice that I would like to consider today.

The second pillar is work-integrated learning. Universities across the world are responding to the expectations of governments, employers and students for the curriculum to better prepare graduates for work through a fuller embrace of work-integrated learning (WIL). WIL is used to describe a range of experiential education approaches that intentionally connect the education of students to the world of work through university-workplace partnerships (McRae 2014). As Cooper, Orrell and Bowden (2010, p. 1) argue, the integrative element of WIL is significant 'because the principal purpose is the nexus of work and learning; each informs and critiques the other'. In other words, WIL is not just our students learning to work, they're working to learn. WIL can be a transformative learning experience for students (and indeed community partners) provided that it is embedded in a rigorous curriculum-enabled learning framework and grounded in tripartite relationships based on the principles of reciprocity and mutual benefit (Cooper, et al 2010; Sachs & Clark 2017). Done well, WIL not only produces work-ready graduates who can apply, integrate, consolidate, and challenge theoretical knowledge in practical settings, but (at least) equally importantly, well-rounded and actively engaged citizens who can critically reflect on and advance the public purpose and social impact of their profession. WIL should thus be integrative in every sense; in turn, ensuring WIL's integrity requires critical attention to, and integration of, its purpose and the processes by which it is implemented (Hartley, Saltmarsh & Clayton 2010; Sachs & Clark 2017).

It was with these two integrative agendas in mind that, almost a decade ago, a major curriculum reform and renewal initiative was enacted at Macquarie University. In this Address I elaborate how, as a research-intensive, comprehensive, metropolitan university, Macquarie responded to global and local pressures and pedagogical imperatives to develop an undergraduate curriculum that aspires to be distinctive, challenging, and transformative: one that meets the needs – personal and professional – of students as they transition into a world of complex social and technological change. In particular I trace the path by which a central plank of the re-imagined curriculum, a community-engaged experiential learning program called PACE (Professional and Community Engagement) was conceived and implemented across the institution. Founded on the principles of reciprocity, the aspiration of PACE is for the students and faculty of the University to contribute more deeply and broadly to the work of its community partners. In this Address I explore key dimensions of the PACE program, including challenges faced in embedding it institution-wide, with particular attention to how PACE has impacted learning frameworks and experiences in the (now School of) Engineering at Macquarie.

Some ten years down the track, all Macquarie undergraduates now participate in some form of community-engaged, work-integrated learning experience through PACE as part of their study programs, but the integrative challenge facing the University is far from over. A range of quantitative and qualitative evidence suggests that, while PACE has positively impacted the learning experience, engagement, outcomes, career path trajectories and sense of life purpose of our students, for too many of them PACE comes too late in their degree. (Most PACE units are taken in a student's last year of undergraduate studies.) A common refrain from students is that an earlier encounter with practice would have helped them clarify personal and professional purpose and goals, shaped their choice of major, and more deeply engaged them in their studies to much greater effect. Similarly, feedback from many community partners suggests that earlier, longer, and repeated WIL engagements would enable them to better align student placements with their own organizational mission and goals. Which brings me to the third and final pillar of integration I wish to touch on today: the potential power of a truly practice-based approach to education.

What does it mean for a discipline – for a whole University – to embrace a practice-based approach to education? As Boud (2013) argues, too often this term is loosely applied to all manner of practice-based activities (internships, service learning, practicums, co-op) without sufficient critical attention to its three key components, 'practice', 'based' and 'education'. 'To be practice-based means more than just a course with "added practice"', he observes (2013, p. 56). Boud argues that basing an education in practice requires a fundamental reconceptualization of core disciplinary (and interdisciplinary) curriculum and pedagogical practice such that practice (rather than theory) is its central, organizing feature. Theory is still an integral part of student learning, to be sure, but that learning takes place in the context of theory's application, not in a separate academic domain. Adopting an ontology of practice informed by practice theorists such as Schatzki and Gherardi, Boud frames a practice-based education as one that actively, systematically and ubiquitously engages students in learning that is embodied, materially mediated, relational, situated, co-created and emergent. Right throughout their course: not just, as with PACE currently, in their final year.

As we look to the future of both PACE and Engineering at Macquarie, a key priority is to consider how we can more systematically embrace such a practice-based approach to education in our program design and pedagogy. This aspiration is based on a firm, evidence-based belief that such an approach will better prepare our students for their professional, personal and interpersonal lives. In doing so we seek to learn from extant examples of integrative approaches to curricular and pedagogical reform that adopt a practice-based approach to education, many of which are drawn from the field of engineering and a number of which will be discussed throughout this 28th Conference of Australasian Engineering Educators. Trevelyan (2010, p. 175) has described the foundation of engineering practice as 'distributed expertise enacted through social interactions between people'. To me this phrase also speaks to the sorts of integrative capabilities and social practices that will enable 21st century graduates in (and beyond) any discipline to lead meaningful, rewarding and socially productive lives.

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SPEAKER BACKGROUND

Lindie Clark is the Academic and Programs Director of Macquarie University's unique Professional and Community Engagement program (PACE). PACE provides work integrated learning experiences to all undergraduate students at Macquarie as an integral part of their study program. Prior to taking up this role she was the Director of the University's Health Studies program, where she ran a PACE unit for many years. With two other colleagues, she was awarded an Australian Learning and Teaching Council Citation for 'Outstanding Contributions to Student Learning' for efforts in building Sustainable Work-Integrated-Learning programs in the Faculty of Science. Prior to joining Macquarie University Lindie worked in a range of regulatory agencies in the health, employment and industrial relations fields. As a Harkness Fellow she completed a Master of Public Administration at Harvard University's Kennedy School of Government in the mid-1990s. Lindie is also a Trustee of the Dusseldorp Skills Forum, a not-for-profit organisation that works to enhance the opportunities for education, skills and employment for all young people, particularly those who don't succeed in the 'mainstream'. Seeing students apply their university learning in real world settings, and in so doing realise the valuable contribution they can make to the broader community, is one of the most rewarding Learning and Teaching experiences Lindie has had in her career. PACE extends such opportunities to all Macquarie students.

Collaborative evidence-based program improvement processes in Engineering

BRIAN FRANK, NATALIE SIMPER, JAKE KAUPP – Queen's University

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Students learn by repeated cycles of completing well-designed tasks, receiving feedback, and reflecting on both, where the tasks in the engineering context are often reports, case studies, assignments, projects, and exams. Generally feedback tends to be both developmental, in the form of specific written or oral comments for improvement, and evaluative in the form of marks or grades assigned to assessment points. These assessments often drive student learning, and can be designed not only to provide feedback, but if to provide evidence about how students are learning over time.

We are developing a collaborative approach to assessment provides quality feedback about learning, and assessment to inform program improvement. We have been doing both research and development into effective approaches that will help departments develop collaborative assessment processes that directly encourage instructors to think about their teaching, and also provide data to leaders to enable decisions about program changes for improvement. We are a collaborator in first and second rounds of Ontario's Learning Outcomes Assessment Consortium, where recently completed a four year longitudinal study of student learning in critical thinking, problem solving, and written communication using both standardized tests and non-standardized assessment of course work using generic rubrics. We are studying how the assessment can encourage instructors and programs to think carefully about their goals and learning environment, and how data provided to them about their own students can improve course delivery.

We have found that asking instructors to articulate how their assessment meets their own (sometimes unstated) learning goals leads to very useful conversations, and often changes in delivery. The study has produced key principles for sustainable and usable program-wide assessment, and a rich understanding of our own student development. We are able to measure student learning over a four year span, and compare the cost and impact of several approaches.

We are using principles from the change management literature to build a community of practice around assessment, including assessment facilitators who can work with specific sectors (science, social science, humanities, and engineering) in such a way that their key tasks deliberately align with their learning goals and can provide data that can be aggregated across many courses and years to understand how students are learning.

SPEAKER BACKGROUND

Dr. Brian Frank is the inaugural Associate Dean (Teaching and Learning) in the Faculty of Engineering and Applied Science. He received his B.Sc. (1997), M.Sc. (1999) and Ph.D. (2002) degrees in electrical and computer engineering from Queen's University in Kingston.

Dr. Frank joined Queen's in 2001 as a Teaching Fellow in the Department of Electrical and Computer Engineering, progressing through the ranks to Full Professor in 2016. From 2004-2006, Dr. Frank was an Educational Development Faculty Associate in the Instructional Development Centre, now called the Centre for Teaching and Learning (CTL). In 2008, he was appointed Director (Program Development) in the Faculty of Engineering and Applied Science, overseeing curriculum development, assessment and outcomes-related accreditation processes, and education technology. Dr. Frank was awarded the endowed DuPont Canada Chair in Engineering Education Research and Development in 2010.

Dr. Frank is one of the co-founders of the Canadian Engineering Education Association and over the past five years has coordinated the Engineering Graduate Attribute Development (EGAD) Project, working with the National Council of Deans of Engineering and Applied Science and the Canadian Engineering Accreditation Board to develop national guidelines and resources for outcomes assessment in engineering education.

Dr. Frank has been recognized with several awards, including a nomination from Queen's University for the 3M National Teaching Fellowship in 2016, the Chancellor A. Charles Baillie Teaching Award in 2011, and the 2010 Engineering Society's Golden Pillar award.

Why do we do engineering?

JAMES TREVELYAN – University of Western Australia

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Why is it that students find it hard to explain the value of engineering?

Why do most engineers find it hard to explain the value of their work to employers and investors, even governments? What's the social value contributed by engineers?

These are fundamental questions and students don't learn answers in their studies.

Why not? A lack of theory makes it hard to teach answers.

Working with Bill Williams in Portugal, James set out to investigate value creation in the engineering enterprise and together they discovered a major gap in business and economics literature. Engineering value creation has been associated with innovation and entrepreneurs. However most engineers have few if any innovation opportunities so the means by which they contribute value is unclear.

Using data from their research studies on engineers over 15 years several countries, they identified many ways in which engineers create and protect existing value, without any innovation.

Many engineering projects fail because engineers don't understand how much value is created and protected in seemingly mundane and boring activities.

In this talk, James will explain their new theory that explains engineering value creation and how educators could make this a part of any normal engineering coursework.

SPEAKER BACKGROUND

Emeritus Professor James Trevelyan is a practicing professional engineer, engineering educator and researcher with 45 years of experience and has recently become a start-up entrepreneur. In 2002, he was elected a Fellow of the Institution of Engineers Australia.

He is best known internationally for pioneering research that resulted in sheep shearing robots from 1975 till 1993. He and his students produced the first industrial robot that could be remotely operated via the internet in 1994.

From 1996 till 2002 he researched landmine clearance methods and since 2002 he has researched engineering practice and recently published significant new findings in his book "The Making of an Expert Engineer" challenging many conventional assumptions among engineers and educators. Using his research, James helped define the current professional competency standards used by Engineers Australia.

Professor Trevelyan's web pages are at:

JamesPTrevelyan.com

www.closecomfort.com

www.mech.uwa.edu.au/jpt

INVITED SPEAKER ABSTRACTS

Multi-disciplinary based learning - Successes of the Sydney Opera House MADE program

CHRIS ARKINS – Steensen Varming

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The values of combining academic based learning with practical hands on experience particularly for engineers is well known. The life lessons I was to learn while undertaking the sandwich course offered by the University of Technology Sydney at the time, provided skills and experience which has underpinned my career to date.

As a profession the industry has a responsibility to invest in the education and training of students in addition to their tertiary based studies. Whilst industry based training is valued, for the Built Environment there are clear benefits to be gained through a Multi-Disciplinary based experience.

The Sydney Opera House is a great example of what can be delivered by a design team from an idea to a monument of engineering and architectural beauty. The collaborative spirit and pursuit of design excellence between engineers and architects is what provides the foundation for the creation of great buildings.

Also known as the Multidisciplinary Australian Danish Exchange, MADE is an extra-curricular program established by the Sydney Opera House in 2013 on their 40th anniversary and is offered to Australian and Danish students of architecture, engineering and design,

The aims of MADE are to;

- Promote international and multidisciplinary interaction between students of architecture, engineering and design;
- Foster cultural relationships between Denmark and Australia; and
- Support the knowledge and understanding of Danish architect Jørn Utzon and the Utzon Design Principles

This presentation will provide an overview of the Sydney Opera House MADE program and the positive benefits and experiences we have seen with the students in the three years the program has been running.

SPEAKER BACKGROUND

Chris is a Director of Steensen Varming, who enjoys the demands that accompany his role in developing and coordinating the delivery of specialist low energy and sustainable design services across their global studios.

He has a driving passion for sustainable low energy design and introduces innovative solutions that provide the functionality and technical detail that complement some of the best award winning architecture both in Australia and abroad.

He began his career at Steensen Varming initially as a mechanical engineer and developed his skills in sustainable design some 20 years ago.

Chris manages the regional operations for both Sydney and Hong Kong studios and leads and coordinates Steensen Varming's commitment to sustainable design and is a strong advocate to the company's ethos of delivering designs that are intelligent, valuable and elegant.

Chris lectures at the University of Sydney and University of Technology Sydney and is a mentor and partner of the Sydney Opera House MADE (Multidisciplinary Australian Danish Exchange) program.

Directions for Engineering Education: the Engineer of 2035

FACILITATOR: **ROBIN KING** – Australian Council of Engineering Deans

robin.king@uts.edu.au

CONTEXT

The 2035 graduate cohort will start school next year. School education will prepare them for good citizenship and further study and employment, including in engineering. A 2015 report on Australia's future workforce identified engineering professionals amongst the jobs "least likely to be automated" and needing the largest additional proportion (11.7%) to meet Australia's requirements as a competitive economy by 2035.

Such statements and other indicators should challenge thinking and promote action amongst Australia's engineering profession and engineering educators. We know that engineering work is both creating and using more and more automated tools and techniques, as well as developing and using new (and old) materials and energy sources. Engineers – and others who are educated in engineering – are exercising expertise and judgement in increasingly complex projects across a wide range of areas of the economy. Globalisation offers unprecedented opportunities for engineering innovation and enterprise.

We also know that the employment rates for Australian engineering graduates have dropped in recent years while employers' demand for experienced engineers has increased. The proportion of engineering commencers in the first degree domestic total has not grown over the last decade, and within the engineering cohort, the proportion of women has increased only slightly, to almost 16%. The numbers of Australian engineering professionals taking up advanced technical studies (as opposed to courses in project management) is quite low.

Past reviews of engineering education in Australia have reported that the system delivers broadly fit-for-purpose entry-level graduates for professional engineering practice. Over the past two decades Australian engineering education has been improved by having greater explicit outcomes-focus and using stronger student-centred pedagogies. At the same time, as noted earlier, low participation of women persists. Relatively low levels of engagement with engineering practice in many programs probably contribute to employers' concerns about graduates' employability skills. Programs remain bound to traditional areas of practice, and offer limited opportunities for graduates to gain interdisciplinary knowledge and perspectives sought by some employers and commentators. New educational technologies challenge current practices.

APPROACH

The Australian Council of Engineering Deans (ACED) is proposing to undertake a review to examine strategically the challenges and opportunities for engineering education for "The Engineer of 2035". This session of AAEE-2017 is a prequel to this review and will provide an opportunity for Australia's engineering educators to raise and discuss key issues of concern in shaping the future directions for engineering education.

The plenary session will commence with short statements from each member of a panel of four distinguished engineers, all with industry and academic experience and high standing in the professional engineering community. This will be followed a Q and A session for conference participants to raise key issues.

FACILITATOR'S BACKGROUND

Emeritus Professor Robin King is a consultant with the Australian Council of Engineering Deans. He previously served as ACED's executive officer and led several engineering education projects, including the 2007-8 review of engineering education. Robin is past chair of both Engineers Australia's Accreditation Board and the Sydney Accord. Robin practised communications engineering in industry and several universities, and was PVC for IT, Engineering and the Environment at UniSA during 1997 to 2007. He has been involved with AAEE since 1989, and is a Fellow of the Academy of Engineering and Technology (ATSE).

PANEL MEMBERS' BACKGROUND

Professor Ian Burnett has been Dean of the Faculty of Engineering and Information Technology at UTS since December 2014. Specialising in signal processing engineering, he has worked at GEC-Marconi, Vodaphone and Motorola, and at the University of Wollongong and RMIT. From 2003-2007, Ian was Australian Head of Delegation at the ISO/IEC standardisation group MPEG, where he also chaired the Multimedia Description Schemes subgroup. He continues to be actively involved in ISO/IEC SC29, the host committee for the MPEG and JPEG families of standards. Ian is Deputy President of ACED.

Professor Kourosh Kayvani is Managing Director – Design, Innovation and Eminence, Aurecon. In his 28 years in the industry, he has played key roles in engineering of many award winning projects across the globe. In 2006, at 39 years of age, he won the prestigious IABSE Prize from the International Association for Bridge and Structural Engineering for his work on long span structures worldwide. He was listed in Engineers Australia's Top 100 most influential engineers in 2009 and won the prestigious John Connell Gold Medal from EA's Structural College in 2016, and was elected a Fellow of ATSE in 2017. Kourosh has held Professorial appointments at University of Sydney and UNSW for the last 10 years.

Mary-Anne Stuart is the Principal Electrical Engineer at H.I. Fraser. Her career has taken her all over Australia in Electrical, Chemical and Mechanical Engineering and Management. She is passionate about supporting women in engineering throughout their lives and as the Engineers Australia Women in Engineering Outreach coordinator, Mary-Anne runs the annual Experience It Student Conference for Girls in Years 9-11 with 8 universities in NSW and the ACT She also teaches Leadership and Ethics at UNSW and is a mentor to female undergraduates at UTS and UNSW. Through EA WIE, she also mentors qualified engineers. She was recently elected a Fellow of Engineers Australia and is currently studying a Masters of Engineering Science in Sustainable Systems at UNSW.

Emeritus Professor Elizabeth Taylor is a civil engineer with design and construction management experience. She worked in academe for many years and presently is a consultant to Charles Sturt University and the Department of Defence. Elizabeth is Chair of RedRAustralia, a humanitarian NGO, and RedRInternational. She also chairs Engineers Australia's Accreditation Board and is Deputy Chair of the Washington Accord. In 2004 Elizabeth was appointed an Officer of the Order of Australia. She is an ATSE Fellow.

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Professor Darren Bagnall
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DETAILED PROGRAM: **SUNDAY 10TH DECEMBER 2017**

5.30pm–7.00pm	Pre-conference Registration	Conference Foyer
6.00pm–8.00pm	Welcome Reception	Conference Foyer

DAY 1: **MONDAY 11TH DECEMBER 2017**

Opens 8.30am		**Conference registration and information desk**	Conference Foyer
9.00am–9.40am	Opening Ceremony	**Welcome to Country by Karen Smith**	The Grand Ballroom
		Welcome by Conference Chair - Professor Graham Town	The Grand Ballroom
		Opening by Professor S Bruce Dowton (Vice Chancellor, Macquarie University)	The Grand Ballroom
9.40am–10.25am	Keynote presentation	**Lindie Clark (Academic and Programs Director, PACE, Macquarie University) - "Integrative practice in the making of a 21st century graduate"** *Chairperson - Professor Graham Town*	The Grand Ballroom
10.25am-10.30am		Delegate's group photograph	The Grand Ballroom
10.30am–11.00am		Morning Tea	

Parallel sessions					
	Clarendom Room	**Norfolk Room**	**Cutler Room**	**Barton Room**	**Clontarf Room**
11.00am–12.30pm	Parallel session: M1A, Theme: C1, Chair: M. Symes	Parallel session: M1B, Theme: C1, Chair: AJ. Hunter	Parallel session: M1C, Theme: C2, Chair: L. Johns-Boast	Focus session: M1S1, Chair: Bennet and Male	Workshop 107: Sharing Intro-Circuits Teaching Experience for Innovative Practice - **David Lowe, Roger Hadgraft and Xi Jin**
12.30pm–1.30pm	Lunch Break				
1.30pm–3.00pm	Parallel session: M2A, Theme: C1, Chair: M. Jollands	Parallel session: M2B, Theme: C1, Chair: J. Swan	Parallel session: M2C, Theme: C2, Chair: M. Marcus	Parallel session: M2D, Theme: C4, Chair: C. Whittington	Workshop 73:Planning Engagement with Professional Practice throughout the Program - **Sally Male, Doug Hargreaves and David Pointing**
3.00pm–3.30pm	Afternoon Tea				
3.30pm–5.00pm	Parallel session: M3A, Theme: C1, Chair: R. Goldsmith	Parallel session: M3B, Theme: C1, Chair: M. Al-Rawi	Parallel session: M3C, Theme: C3, Chair: G. Miao	Parallel session: M3D, Theme: C4, Chair: C. Kutay	Workshop 63: Integrating Creativity Into Curriculum: Let Us Listen To Students - **Iouri Belski**
5.00pm–5.15pm	**Day 1 Closing**				

DAY 2: **TUESDAY 12TH DECEMBER 2017**

Opens 8.30am	Conference registration and information desk					Conference Foyer
9.00am–9.45am	**Keynote Presentation**	**Professor Brian Frank (Queen's University, Canada) - "Collaborative evidence-based program improvement processes in Engineering"** *Chairperson: Professor Darren Bagnall*				The Grand Ballroom
9.45am–10.15am	**Special Guest Lecture**	**Chris Arkins - "Multi-disciplinary based learning - Successes of the Sydney Opera House MADE program"** *Chairperson: Professor Darren Bagnall*				The Grand Ballroom
10.15am–10.40am	Morning Tea					
	Parallel sessions					
	Clarendom Room	**Norfolk Room**	**Cutler Room**	**Barton Room**	**Clontarf Room**	
10.40am–12.10pm	Parallel session: T1A, Theme: C1, Chair: B. McBride	Workshop 236: Integrating sustainability into engineering education via project based curricula: a national sustainability competition - **Michele Rosanoa, Roger Hadgraftb, and Sally Male**	Parallel session: T1C, Theme: C3, Chair: I. Skinner	Focus session: T1S2, Chair: G. Cascini	Workshop 90: Resources for developing a Management System for Engineering Education (MaSEE) - **Bernadette Foley, Edward Palmer, Tiffany Gill, Bouchra Senadji and Elisa Martinez Marroquin**	
12.10pm–1.30pm	Lunch in Conference Foyer and **AAEE AGM in Cutler Room**					
1.30pm–3.00pm	Parallel session: T2A, Theme: C1, Chair: D. Lowe	Parallel session: T2B, Theme: C1, Chair: T. Harris	Parallel session: T2C, Theme: C5, Chair: N. Tse	Focus session: T2S2, Chair: P. Livotov	Workshop 42: Integrating Community Engagement into Engineering Service-Learning - **Jennifer Turner and Jeremy Smith**	
3.00pm–3.30pm	Afternoon Tea					
3.30pm–5.00pm	Parallel session: T3A, Theme: C1, Chair: R. Eaton	Workshop 234: Professional Performance in University Education and Work Integrated Learning - **Ashley Brinson, Brendyn Williams, John Nurse**	Parallel session: T3C, Theme: C3, Chair: S. Daniel	Focus session: T3S2, Chair: L. Chechurin	Workshop 100: Adapt your teaching: Create Your Own Interactive Adaptive Tutorial - **Heather Weltman**	
6.30pm–10.30pm	**CONFERENCE DINNER** (The Grand Ballroom, Novotel Manly)					
	Day 2 Closing					

DAY 3: WEDNESDAY 13TH DECEMBER 2017

Opens 8.30am	Conference registration and information desk					Conference Foyer
9.00am–9.45am	Keynote Presentation	**Professor James Trevelyan (University of Western Australia) - "Why do we do engineering?"** *Chairperson: Dr Nazmul Huda*				The Grand Ballroom
9.45am–10.40am		**Panel Discussion facilitated by Robin King on "Directions for Engineering Education: the Engineer of 2035"**				The Grand Ballroom
10.40am–11.10am	Morning Tea					
Parallel sessions						
	Clarendom Room	**Norfolk Room**	**Cutler Room**	**Barton Room**	**Clontarf Room**	
11.10am–12.40pm	Parallel session: W1A, Theme: C2, Chair: A. Goncher	Parallel session: W1B, Theme: C2, Chair: T. Goldfinch	Workshop 163: "It's Not all technical …": - A pragmatic approach to 'soft skills' development across a program - **Nicholas Tse, Natalie Spence and Fiona Jones**	Focus session: W1S3, Chair: Smith and Mazzurco	Workshop 190: Assessing practical skills in engineering - **Siva Krishnan and Tiffany Gunning**	
12.40pm–1.40pm	Lunch Break					
1.40pm-2.50pm	Parallel session: W2A, Theme: C5, Chair: D. Inglis	Workshop 232: Designing Authentic and Effective Assessments: How can this assist in minimising contract cheating - **Hazel Jones and Jo Devine**	Workshop 83: Another Step Towards an Internationally-Inclusive Framework Characterizing the Impact of Engineering Education Research - **Anne Gardner and Jeremi London**	Focus session: W2S3, Chair: Smith & Mazzurco	Workshop 191: How do we integrate Indigenous perspectives in engineering education? **Juliana Kaya Prpic, Tom Goldfinch and Jade Kennedy**	
2.50pm–3.10pm	Afternoon Tea and preparing Grand Ballroom for conference closing					
3.10pm–3.40pm	**CONFERENCE CLOSING** (G. Town) **Presentation of Best Paper and Best Reviewer Awards** **Closing Remarks and AAEE 2018 Handover**					

THEMES: The current program will consist of the following themed sessions:

Conference Themes:

C1: Integration of theory and practice in the learning and teaching process

C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

C3: Integration of teaching and research in the engineering training process

C4: The role and impact of engineering students and educators in the wider community

C5: Systems perspectives on engineering education

Focus Sessions:

S1: Is Integrated Engineering Education Necessary?
Moderators: Dawn Bennett (Curtin University) and Sally Male (The University of Western Australia)

S2: Educating the Edisons of the 21st Century: integrating thinking heuristics (including TRIZ) into the engineering curriculum.
Moderator: Iouri Belski (RMIT)

S3: Integrating Humanitarianism in Engineering Education
Moderators: Jeremy Smith (Australian National University) and Andrea Mazzurco (Swinburne University of Technology)

PARALLEL SESSIONS

MONDAY 11TH DECEMBER

Session: M1A, Clarendon Room, Chair: M. Symes

Theme: C1 - Integration of theory and practice in the learning and teaching process

Time	Paper #	Title and author
11.00am–11.10am	115	A flipped classroom with low-stakes assessment to maintain student engagement and integrate theory and practice - Braden Phillips and Michael Liebelt
11.10am–11.20am	7	Flipped learning not flopped learning - Cat Kutay, Anthony Kadi and John Canning
11.20am–11.30am	16	A new strategy for active learning to maximise performance in intensive courses - Mohammad Al-Rawi and Annette Lazonby
11.30am–11.40am	174	Laboratory Learning: Hands-on versus Simulated Experiments - Fabian Steger, Alexander Nitsche, Cayler Miley, Hans-Georg Schweiger and Iouri Belski
~~11.40am–11.50am~~	~~213~~	~~The Importance of Student and Faculty Feedback in Development of Virtual Engineering Laboratories - Ali Altalbe and Neil Bergamnn~~ 166
11.50am–12.00pm	227	Researching reflection in an engineering internship program - Alan Parr and Xi Jin
12.00pm–12.30pm		Discussion

Monday 11th December

Session: M1B, Norfolk Room, Chair: AJ. Hunter

Theme: C1 - Integration of theory and practice in the learning and teaching process

Time	Paper #	Title and author
11.00am–11.10am	60	Developing three-dimensional engineers through project-based learning - Sally Inchbold-Busby and Rosalie Goldsmith
11.10am–11.20am	70	Developing students' employability in work placements - Margaret Jollands, Wageeh Boles and J. Fiona Peterson
11.20am–11.30am	17	Engineering Exposure to Professional Practice: Navigating the requirments - William McBride and Bernadette Foley
11.30am–11.40am	157	eLearning initiatives - can their effectiveness really be measured? - Dahlia Han, Melissa Gunn and Rachel Chidlow
11.40am–11.50am	231	An Integrating Teaching Resource for Materials Science and Engineering -Claes Fredriksson and Joel Galos
11.50am–12.00pm	33	Mechanical engineering students' perceptions of workplace mentoring: A case study at a South African University of Technology - Tiyamike Ngonda, Corrinne Shaw and Bruce Kloot
12.00pm–12.30pm		Discussion

Monday 11th December

Session: M1C, Cutler Room, Chair: L. Johns-Boast

Theme: C2 - Interdisciplinary and cross-disciplinary engineering programs and learning environments

Time	Paper #	Title and author
11.00am–11.10am	128	The engineering fundamentals are important...but what are they? - Emily Cook and Llewellyn Mann
11.10am–11.20am	126	Engineers learning about Entrepreneurship: The journey through the lens of an engineering academic - Helen Fairweather, Margarietha de Villiers Scheepers, Renee Barnes, Jane Taylor, Irene Visser and Katryna Starks
11.20am–11.30am	13	An initial step towards developing techno-entrepreneurs in the engineering curriculum - Kourosh Dini and Aaron Blicblau
11.30am–11.40am	226	STEAMpunk Girls Co-Design: Exploring a more Integrated Approach to STEM Engagement for Young Women - Sonia Saddiqui and Maya Marcus
11.40am–11.50am	25	Assessment of Self-Management Skills in a Project-Based Learning Paper - Jonathan Scott, Elaine Khoo, Michael Cree and Sinduja Seshadri
11.50am–12.00pm	135	Cultural Contexts of Learning Preferences: Relative Dominance of Self-Directed versus Other-Directed Learning Styles - Varghese Swamy, Vineetha Kalavally, Ta Yeong Wu, Alena Tan and Jonathan Li
12.00pm–12.30pm		Discussion

PARALLEL SESSIONS (CONTINUED)

MONDAY 11TH DECEMBER		
Session: M1S1, Barton Room, Chair: Bennet and Male		
Theme:S1 - Is Integrated Engineering Education Necessary?		
Time	Paper #	Title and author
11.00am–11.10am	40	Metacognition as a graduate attribute: Employability through the lens of self and career literacy - Dawn Bennett
~~11.10am–11.20am~~	~~176~~	~~Fast-Cars in Schools: a CADET Outreach Initiative - John Long, Simon Cavenett, Jason Steinwedel and Leanne Collins~~
11.20am–11.30am	89	Developing a Management System for Engineering Education (MaSEE) - Bernadette Foley, Tiffany Gill, Bouchra Senadji, Edward Palmer and Elisa Martinez Marroquin
11.30am–11.40am	75	The Emerging Suite of Virtual Work Integrated Learning Modules for Engineering Students - Sally Male
11.40am–11.50am	27	Integrated Engineering may be necessary, but perhaps design would be taken more seriously? - Lynn Berry
11.50am–12.00pm	141	Student-Centred Curriculum Transformation - Roger Hadgraft, Rob Jarman, Justine Lawson and Beata Francis
12.00pm–12.30pm		Discussion

MONDAY 11TH DECEMBER		
Session: M2A, Clarendon Room, Chair: M. Jollands		
Theme: C1 - Integration of theory and practice in the learning and teaching process		
Time	Paper #	Title and author
1.30pm–1.40pm	91	The Warman – Looking Beyond 30 Years - Warren Smith, Craig Wheeler, Colin Burvill, Alex Churches and Tim Riley
1.40pm–1.50pm	9	A Study on Integrating Case-Based Learning into Engineering Curriculum - Eugene Tham and Lori Breslow
1.50pm–2.00pm	32	Characterising the learning dispositions of first year engineering students - Anne Gardner, Keith Willey and Thomas Goldfinch
2.00pm–2.10pm	179	Implementation of Project-Oriented Design-Based Learning in a Second-Year Mechanical/Mechatronics Subject - John Long, Siva Chandrasekaran and Michael Pereira
2.10pm–2.20pm	220	Understanding Engineering Competencies in Practice and its Educational Implication - Xi Jin and Roger Hadgraft
2.20pm–2.30pm	46	Implementing MUSIC Components to Enrich Engineering Capstone Projects: The Students' Perspective and the Instructors' Standpoint - S. Ali Hadigheh and Daniel Dias-Da-Costa
2.30pm–3.00pm		Discussion

MONDAY 11TH DECEMBER		
Session: M2B, Norfolk Room, Chair: J. Swan		
Theme: C1 - Integration of theory and practice in the learning and teaching process		
Time	Paper #	Title and author
1.30pm–1.40pm	225	Running an Open MOOC on Learning in Laboratories - Alexander Kist, Hannah Campos Remon, Lindy Orwin, Andrew Maxwell, Ananda Maiti, Peter Albion and Victoria Terry
1.40pm–1.50pm	213	The Importance of Student and Faculty Feedback in Development of Virtual Engineering Laboratories - Ali Altalbe and Neil Bergamnn
1.50pm–2.00pm	127	Visualising Student Satisfaction - Samuel Cunningham-Nelson, Mahsa Baktashmotlagh and Wageeh Boles
2.00pm–2.10pm	94	Deviating from traditional lectures: Engineering students' perception of active learning - Subeh Chowdhury
2.10pm–2.20pm	20	Designing and Using Self-Paced Tutorials: Lessons from the Pilot - Sasha Nikolic and Raad Raad
2.20pm–2.30pm	87	Students' social and behavioural factors influencing the use of lecture capture technology and learning in engineering education - Anisur Rahman, Mohammad Aminur Rahman Shah and Sanaul Huq Chowdhury
2.30pm–3.00pm		Discussion

PARALLEL SESSIONS (CONTINUED)

MONDAY 11TH DECEMBER

Session: M2C, Cutler Room, Chair: ~~L. Johns-Boast~~ M. Marcus

Theme: C2 -Interdisciplinary and cross-disciplinary engineering programs and learning environments

Time	Paper #	Title and author
1.30pm–1.40pm	168	Creating shared value: An industry project framework - Jennifer Turner and Llewellyn Mann
1.40pm–1.50pm	116	A Problem Shared is a Problem Halved: Benefits of Collaborative Online Engineering L&T Content Development - John Vulic, May Lim, Stefan Felder, Shaun Chan, Jesse Jones and Lorenzo Vigentini
1.50pm–2.00pm	31	Enhancing Technical Writing Skills for Undergraduate Engineering Students - Beverly Coulter, Roslyn Petelin, Justine Gannon, Kate O'Brien and Corrie Macdonald
2.00pm–2.10pm	182	The Immersive Learning Laboratory: employing virtual reality technology in teaching - Jacqueline Thomas, Kiran Ijaz, Benjy Marks and Peter Gibbens
2.10pm–2.20pm	22	Making sense of Learning Management System's quiz analytics in understanding students' learning difficulties - Antonette Mendoza, Harald Sondergaard and Anne Venables
2.20pm–3.00pm		Discussion

MONDAY 11TH DECEMBER

Session: M2D, Barton Room, Chair: C. Kutay

Theme: C4 -The role and impact of engineering students and educators in the wider community

Time	Paper #	Title and author
1.30pm–1.40pm	167	Grounded by values: An emergent engineering practice - Timothy Smith, Alicen Coddington, Jennifer Turner, Llewellyn Mann, Enda Crossin, Emily Cook, Sivachandran Chandrasekaran and Andrea Mazzurco
1.40pm–1.50pm	185	Inclusive engineering education: making engineering degree work for more students - Marina Belkina
1.50pm–2.00pm	146	Engaging prospective students with Mechanical Engineering - Ashlee Pearson, Scott Wordley, Jiachun Huang, Stephanie Duggan and Christopher Meikle
2.00pm–2.10pm	51	Moral Development of Students Entering the Civil Engineering Bachelor - Andrea Mazzurco, Homero Murzi and Ilje Pikaar
2.10pm–2.20pm	3	Aboriginal Engineering - technologies for an enduring civilisation - Cat Kutay and Elyssebeth Leigh
2.20pm–2.30pm	72	Towards integration of the Māori world view and engineering: A case study on student design projects for the Koukourarata community, Aotearoa/New Zealand - Matthew Hughes, Ricardo Bello Mendoza, Manaia Cunningham, Kendra Sharp and Richard Manning
2.30pm–3.00pm		Discussion

MONDAY 11TH DECEMBER

Session: M3A, Clarendon Room, Chair: R. Goldsmith

Theme: C1 - Integration of theory and practice in the learning and teaching process

Time	Paper #	Title and author
3.30pm–3.40pm	125	The use of threshold exams to change students learning culture and provide assurance of learning - Keith Willey and Anne Gardner
3.40pm–3.50pm	71	Student Experiences of Threshold Capability Development in a Computational Fluid Dynamics Unit Delivered in Intensive Mode - Jeremy Leggoe and Sally Male
3.50pm–4.00pm	11	Mapping the Integrated Research Landscape on Gender and Teamwork in Higher Education: 2000-2016 - Kacey Beddoes and Grace Panther
4.00pm–4.10pm	97	Role of Experiential Learning in PM Education - Louis Taborda, Li Liu and Lynn Crawford
4.10pm–4.20pm	80	Engineering as a "Thinkable" Career for Women - Bronwen Cowie, Margaret Paiti and Janis Swan
4.20pm–5.00pm		Discussion

PARALLEL SESSIONS (CONTINUED)

MONDAY 11TH DECEMBER		
Session: M3B, Norfolk Room, Chair: M. Al-Rawi		
Theme: C1 - Integration of theory and practice in the learning and teaching process		
Time	Paper #	Title and author
3.30pm–3.40pm	82	Explicitly teaching teamwork and written communication within a problem based curriculum: Development of a generalised framework - David Holmes and Michelle Lasen
3.40pm–3.50pm	37	Integrating Professional Practice in the Engineering Curriculum: BE/ME Chemical Engineering Students' Experiences in Industry Placements - Homero Murzi, Andrea Mazzurco and Beverly Coulter
3.50pm–4.00pm	117	Through the Looking Glass: Visualising Design Details with Augmented Reality - Nicholas Yee Kwang Tee, Hong Seng Gan, Andy Huynh, Veronica Halupka and Jonathan Li
4.00pm–4.10pm	119	Transformation in Engineering Education – A Case Study of Remote Learning experiences in China - Van Thanh Huynh, Siva Chandrasekaran, John Long, Yufei Guo and Ian Gibson
4.10pm–4.20pm	88	Intensive Mode Teaching for the delivery of engineering content to students at a Chinese university - Peter Doe, Seeta Jaikaran-Doe, Sarah Lyden, Ming Liu, Bingzhong Ren, Peng Yang and Sally Male
4.20pm–5.00pm		Discussion

MONDAY 11TH DECEMBER		
Session: M3C, Cutler Room, Chair: G. Miao		
Theme: C3 - Integration of teaching and research in the engineering training process		
Time	Paper #	Title and author
3.30pm–3.40pm	92	Evaluation of a redesigned Engineering degree founded on project based learning - Mark Tunnicliffe and Nicola Brown
3.40pm–3.50pm	26	Integration of Applied Research in Polytechnic Engineering Education - Hossein Askarinejad and Matt Ramezanianpour
3.50pm–4.00pm	93	Ethics problems found challenging by research students - Iain Skinner
4.00pm–4.10pm	68	Understanding Capacity in Creativity and Problem Analysis among Engineering Students - Dorothy Missingham, Antoni Blazewicz, David Strong, Mei Cheong and Harry Lucas
4.10pm–4.20pm	10	Comparing Students and Practicing Engineers in Terms of How They Bound Their Knowledge - Grace Panther and Devlin Montfort
4.20pm–5.00pm		Discussion

MONDAY 11TH DECEMBER		
Session: M3D, Barton Room, Chair: C. Whittington		
Theme: C4 - The role and impact of engineering students and educators in the wider community		
Time	Paper #	Title and author
3.30pm–3.40pm	224	Integrated Pathways: Connecting the Disconnected - Trudy Harris, Johnny Gordon, Bandana Kumar and Paul Price
3.40pm–3.50pm	153	History and Philosophy of Engineering - Rod Fiford
3.50pm–4.00pm	114	Changing Role of Modern Engineers and Social Responsibility - Sangeeta Karmokar
4.00pm–4.10pm	104	STEM for Women and Ethnic Communities in Aotearoa (New Zealand) - Chris Whittington and Sangeeta Karmokar
4.10pm–4.20pm	49	STEM Intervention Strategies: Sowing the Seeds for More Women in STEM - Miranda Ge and Jonathan Li
4.20pm–5.00pm		Discussion

PARALLEL SESSIONS (CONTINUED)

TUESDAY 12TH DECEMBER		
Session: T1A, Chair: B. McBride		
Theme: C1 - Integration of theory and practice in the learning and teaching process		
Time	Paper #	Title and author
10.40am–10.50am	96	Mixing Teaching Approaches to Maximise Student Learning Experiences - Charles Lemckert and Amir Etemad Shahidi
10.50am–11.00am	105	Towards an informed course design - Bill Collis, Chen Wang, Gerard Rowe, Elizabeth Rata and Graham McPhail
11.00am–11.10am	120	Pointers to Conceptual Understanding - Samuel Cunningham-Nelson, Andrea Goncher, Michelle Mukherjee and Wageeh Boles
11.10am–11.20am	44	Tangible Teaching Tools: The Use of Physical Computing Hardware in Schools - Jarred Benham, Jonathan Li and Linda McIver
11.20am–11.30am	219	The Correlation between Practice Time and Student Improvement in Mathematics - Nigel Shepstone
11.30am–11.40am	53	Refocusing Marking Practices to Enculturate Learning: Developing a Practice Architecture - Alison-Jane Hunter, Dorothy Missingham, Colin Kestell and Linda Westphalen
11.40am–12.10pm	Discussion	

TUESDAY 12TH DECEMBER		
Session: T1C, Chair: I. Skinner		
Theme: C3 - Integration of teaching and research in the engineering training process		
Time	Paper #	Title and author
10.40am–10.50am	74	Using Narrative Research Findings as Student Voice for Providing Insights into Transition Experiences in Engineering Education - Luke Alao and Llewellyn Mann
10.50am–11.00am	95	We Built It and They Came: An Adaptive eLearning Experience - Heather Weltman, Furqan Hussain and Nadine Marcus
11.00am–11.10am	23	What can we do to better support students in Thesis? - Guien Miao, Lynn Berry and David Lowe
11.10am–11.20am	66	Future-Proof Engineers with Transformative Calibres - Serene Lin-Stephens, Shaokoon Cheng and Agisilaos Kourmatzis
11.20am–11.30am	106	Self and Peer Assessment of Teamwork Activities - Jiachun Huang, Scott Wordley and Ashlee Pearson
11.30am–11.40am	198	Application of Research Skills Development Framework (RSDf) in Sustainable Engineering Teaching and Learning - Poovarasi Balan
11.40am–12.10pm	Discussion	

TUESDAY 12TH DECEMBER		
Session: T1S2, Chair: G. Cascini		
Theme: S2 - Educating the Edisons of the 21st Century		
Time	Paper #	Title and author
10.40am–10.50am	218	Australian electrical engineering curricula and development of creativity skills: How do we rate? - Andrew Valentine, Iouri Belski, Margaret Hamilton and Scott Adams
10.50am–11.00am	55	Modelling Innovation Process in Multidisciplinary Course in New Product Development and Inventive Problem Solving - Pavel Livotov
11.00am–11.10am	56	The Allocation of Time Spent in Different Stages of Problem Solving: Problem finding and the development of engineering expertise - Jennifer Harlim and Iouri Belski
11.10am–11.20am	47	International Student Online TRIZ (Teoriya Resheniya Izobretatelskikh Zadach) conferences: organizational experience and perspectives - Viktor Berdonosov, Elena Redkolis and Won Young Song
11.20am–11.30am	131	First year engineering students problem solving in different scenarios. - Aaron Blicblau and Andrew Ang
11.30am–11.40am	65	Engineering Creativity – How To Measure It? - Iouri Belski
11.40am–12.10pm	Discussion	

PARALLEL SESSIONS (CONTINUED)

TUESDAY 12TH DECEMBER		
Session: T2A, Chair: D. Lowe		
Theme: C1 - Integration of theory and practice in the learning and teaching process		
Time	Paper #	Title and author
~~1.30pm–1.40pm~~	~~166~~	~~Inclusiveness in Australian Engineering Education - Simon Cavenett~~ Replaced with paper 176
1.40pm–1.50pm	212	A New Project Management regime - Michael Netherton, Lisa Nelson and Bill McBride
1.50pm–2.00pm	67	A new, common, experiential 'Engineering Practice' course - Dylan Cuskelly and William McBride
2.00pm–2.10pm	203	A "MetroGnome" as a tool for supporting self-directed learning - Jim Morgan, Euan Lindsay and Kevin Sevilla
2.10pm–2.20pm	133	Assessing the efficacy of embedding online laboratories in e-learning tutorials to enhance student engagement - James Theodosiadis, Steve Steyn and Steve Mackay
2.20pm–2.30pm	140	Quantitative Research Design to Evaluate Learning Platforms and Learning Methods for Cyber-security Courses - Kamanashis Biswas and Vallipuram Muthukkumarasamy
2.30pm–3.00pm		Discussion

TUESDAY 12TH DECEMBER		
Session: T2B, Chair: T. Harris		
Theme: C1 - Integration of theory and practice in the learning and teaching process		
Time	Paper #	Title and author
1.30pm–1.40pm	76	Long term study of attendance rates in a civil engineering unit of study - Tim Wilkinson
1.40pm–1.50pm	108	Redeveloping an introductory course in microcontrollers through the lens of educational theory - Bill Collis, Gerard Rowe and Claire Donald
1.50pm–2.00pm	79	Offshore Students' Perception of Intensive Engineering Subject Delivery: Case Study at an Indian University - Kali Prasad Nepal
2.00pm–2.10pm	184	Constructivist Simulations for Path Search Algorithms - Alan Blair, David Collien, Dwayne Ripley and Selena Griffith
2.10pm–2.20pm	84	Student Expectations: The effect of student background and experience - Brent Phillips, Trudy Harris and Lynette Johns-Boast
2.20pm–3.00pm		Discussion

TUESDAY 12TH DECEMBER		
Session: T2C, Chair: N. Tse		
Theme: C5 - Systems perspectives on engineering education		
Time	Paper #	Title and author
1.30pm–1.40pm	165	Defending interpretivist knowledge claims in engineering education research - Scott Daniel, Llewellyn Mann and Alexander Mazzolini
1.40pm–1.50pm	118	A systematic approach to teaching and learning development in engineering - Tiffany Gunning and Siva Krishnan
1.50pm–2.00pm	207	Creativity in Mechanical Design: Exploring Suitable Methodologies for Better Practice - Paul Briozzo, Rodney Fiford and Peter Lok
2.00pm–2.10pm	136	An Engineering Approach to Engineering Curriculum Design - Michael Liebelt, Stephanie Eglinton-Warner, Wen Soong, Brian Ng, Braden Phillips, Said Al-Sarawi and Matthew Sorell
2.10pm–3.00pm		Discussion

PARALLEL SESSIONS (CONTINUED)

TUESDAY 12TH DECEMBER		
Session: T2S2, Chair: P. Livotov		
Theme: S2 - Educating the Edisons of the 21st Century		
Time	Paper #	Title and author
1.30pm–1.40pm	45	Introducing TRIZ Heuristics to Students in NZ Diploma in Engineering - Konstantin Shukhmin and Iouri Belski
1.40pm–1.50pm	111	What is easier to solve: open or closed problems? - Christoph Dobrusskin
1.50pm–2.00pm	216	Can Idea Generation Techniques Impede Effective Ideation? - Andrew Valentine, Iouri Belski and Margaret Hamilton
2.00pm–2.10pm	21	TRIZ - Trans-disciplinary innovation methodology - Bohuslav Bušov and Vladimír Dostál
2.10pm–2.20pm	36	Teaching creativity creatively - Iuliia Shnai and Leonid Chechurin
2.20pm–2.30pm	69	Prior Knowledge and Student Performance in Idea Generation - Gavin Buskes and Iouri Belski
2.30pm–3.00pm	Discussion	

TUESDAY 12TH DECEMBER		
Session: T3A, Chair: R. Eaton		
Theme: C1 - Integration of theory and practice in the learning and teaching process		
Time	Paper #	Title and author
3.30pm–3.40pm	159	The Self Directed Learning Styles Survey as a Predictor of Success in a Problem-Based Learning Environment - Kevin Sevilla, Andrea Goncher and Jim Morgan
3.40pm–3.50pm	142	Improving Presentation Skills of First-Year Engineering Students using Active Video Watching - Antonija Mitrovic, Peter Gostomski, Alfred Alfred Herritsch and Vania Dimitrova
3.50pm–4.00pm	214	Worked Example Videos as a Valuable Blending Learning Resource in Undergraduate Engineering Units - Sarah Barns, Edmund Pickering and Les Dawes
4.00pm–4.10pm	145	Educats: A Community of Practice - Jiachun Huang, Ashlee Pearson, Nathan Sherburn, Thanh Huynh Nguyen, Tony Vo and Veronica Halupka
4.10pm–4.20pm	160	Mining students work experience reports - Dorian Hanaor, David Airey and Peter Café
4.20pm–5.00pm	Discussion	

TUESDAY 12TH DECEMBER		
Session: T3C, Chair: S. Daniel		
Theme: C3 - Integration of teaching and research in the engineering training process		
Time	Paper #	Title and author
3.30pm–3.40pm	194	A systemic approach to improving tutor quality in a large unit - Peter O'Shea and Philip Terrill
3.40pm–3.50pm	121	Staff competencies/capabilities required and challenges faced when delivering project based learning courses - Nicola Brown and Mark Tunnicliffe
3.50pm–4.00pm	169	Effective use of Zoom technology and instructional videos to improve engagement and success of distance students in Engineering. - Abu Shadat Muhammad Sayem, Benjamin Taylor, Mitchell Mcclanachan and Umme Mumtahina
4.00pm–4.10pm	183	Towards the development and delivery of sustainable assessment in foundation engineering studies - Benjamin Taylor, Lois Harris and Joanne Dargusch
4.10pm–4.20pm	215	Case study based teaching of process economics in the context of Chemical Engineering - Meng Wai Woo
4.20pm–5.00pm	Discussion	

PARALLEL SESSIONS (CONTINUED)

TUESDAY 12TH DECEMBER		
Session: T3S2, Chair: L. Chechurin		
Theme: S2 - Educating the Edisons of the 21st Century		
Time	Paper #	Title and author
3.30pm–3.40pm	110	A scientific framework for testing creativity enhancing techniques - Niccolò Becattini and Gaetano Cascini
3.40pm–3.50pm	150	Developing student capacity for Start Up through integrating engaged, action and threshold learning models with a design thinking framework. - Selena Griffith
3.50pm–4.00pm	223	TRIZ Education in Mainland China - Lixin Wang
4.00pm–4.10pm	54	Developing a simulated Work-Integrated-Learning (WIL) program to improve problem solving skills of young engineers -
4.10pm–4.20pm	217	Analysis of Usage for Two Digital Format Ideation Templates - Andrew Valentine, Iouri Belski and Margaret Hamilton
4.20pm–5.00pm	Discussion	

WEDNESDAY 13TH DECEMBER		
Session: W1A, , Chair: A. Goncher		
Theme: C2 - Interdisciplinary and cross-disciplinary engineering programs and learning environments		
Time	Paper #	Title and author
11.10am–11.20am	177	Generating an architectural brief for a twenty-first-century engineering education working and learning environment - Alicen Coddington and Llewellyn Mann
11.20am–11.30am	129	In-Class and Asynchronous Student Response Systems: A Comparison of Student Participation and Perceived Effectiveness - Lokesh Padhye and Marion Blumenstein
11.30am–11.40am	18	Embedding Authentic Practice Based Learning in Engineering Undergraduate Courses - Chris Whittington, Tim Anderson and Andy Conner
11.40am–11.50pm	151	Motivating diverse student cohorts with problem based learning in undergraduate control engineering - Felix H. Kong, Brian K.M. Lee and Ian R. Manchester
11.50am–12.00pm	15	Interdisciplinary Collaborative Teaching in Project-Based Learning Approach - Anna Lyza Felipe, Thanh Chi Pham, Minh Xuan Nguyen and Edouard Amouroux
12.00pm–12.40pm	Discussion	

WEDNESDAY 13TH DECEMBER		
Session: W1B, Chair: T. Goldfinch		
Theme: C2 - Interdisciplinary and cross-disciplinary engineering programs and learning environments		
Time	Paper #	Title and author
11.10am–11.20am	139	Attitudes Towards Software Engineering in Industry - Catherine Watson and Kelly Blincoe
11.20am–11.30am	188	Towards a framework for evaluating diversity in STEM outreach programs - Sam Cheah and Christopher Browne
11.30am–11.40am	235	Integrated Engineering – Implementation and Transition G. Town
11.40am–11.50pm	197	What Difference Do the Differences Make: Cultural Differences as Learning Resources in a Global Engineering Course - Yun Dai and Ang Liu
11.50am–12.00pm	230	Teaching Advanced Computing Technologies to Managers, Engineers and Other Professionals - Ljiljana Brankovic, Stephan Chalup and Mark Wallis
12.00pm–12.40pm	Discussion	

PARALLEL SESSIONS (CONTINUED)

WEDNESDAY 13TH DECEMBER		
Session: W1S3, Chair: Smith and Mazzurco		
Theme: S3 - Integrating Humanitarianism in Engineering Education		
Time	Paper #	Title and author
11.10am–11.20am	64	The Rise of Humanitarian Engineering Education in Australasia - Jeremy Smith, Nick Brown, Alison Stoakley, Jennifer Turner, Bianca Anderson and Alanta Colley
11.20am–11.30am	78	Evaluating Humanitarian Engineering Education Initiatives: A Preliminary Literature Review - Andrea Mazzurco and Homero Murzi
11.30am–11.40am	99	Making a difference: creating opportunities for undergraduate students to contribute to humanitarian engineering projects - Fiona Johnson, Stephen Foster, Carla Frankel, Sam Johnson, Stephen Moore, Richard Stuetz and Jacqueline Thomas
11.40am–11.50pm	186	Lessons learned from the design and delivery a new major in Humanitarian Engineering - Jacqueline Thomas, Petr Matous, Peter Cafe and Abbas El-Zein
11.50am–12.40pm	Discussion	

WEDNESDAY 13TH DECEMBER		
Session: W2A, Chair: D. Inglis		
Theme: C5 - Systems perspectives on engineering education		
Time	Paper #	Title and author
1.40pm–1.50pm	39	Engineering Student Use of Facebook as a Social Media 'Third Space' - Stuart Palmer and Tiffany Gunning
1.50pm–2.00pm	98	Professors' Discourses on Why Underrepresentation Matters - Kacey Beddoes
2.00pm–2.10pm	233	Retention in the School of Engineering of the Universidad Pontificia Bolivariana Medellín-Colombia - Bibiana Arango and Ana Maria Tamayo Mejía
2.10pm–2.20pm	109	Does 'just in time' design thinking enhance student interest and appreciation of customer needs in the design of machine elements? - Huaizhong Li and Sushila Chang
2.20pm–2.50pm	Discussion	

WEDNESDAY 13TH DECEMBER		
Session: W2S3, Chair: Smith & Mazzurco		
Theme: S3 - Integrating Humanitarianism in Engineering Education		
Time	Paper #	Title and author
1.40pm–1.50pm	171	Integrating Social Impact throughout an Engineering Curriculum - Scott Daniel and Llewellyn Mann
1.50pm–2.00pm	81	The role of a humanitarian focus in increasing gender diversity in engineering education - Alison Stoakley, Nick Brown and Sarah Matthee
2.00pm–2.10pm	162	Development of Global Competencies through Humanitarian Engineering Experiences - Andrea Goncher and Josh Devitt
2.10pm–2.20pm	196	What can be learned from the humanitarian successes and failures of Thomas Edison - Peter O'Shea
2.20pm–2.50pm	Discussion	

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Renew old friendships and make new acquaintances as we welcome you to Manly in Sydney, New South Wales.

Canapés and drinks will be served in the AAEE 2017 Exhibition at the Novotel Sydney Manly Pacific.

DATE:	SUNDAY 10 DECEMBER 2017
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DRESS:	BUSINESS CASUAL
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CHILDREN'S TICKETS:	$59.00

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DATE:	TUESDAY 12 DECEMBER 2017
TIME:	18:30 – 22:30, DOORS OPEN AT 19:00
VENUE:	NOVOTEL SYDNEY MANLY PACIFIC
DRESS:	BUSINESS CASUAL
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55 North Steyne, Manly, New South Wales 2095 AUSTRALIA

Ph: +61 2 9977 7666

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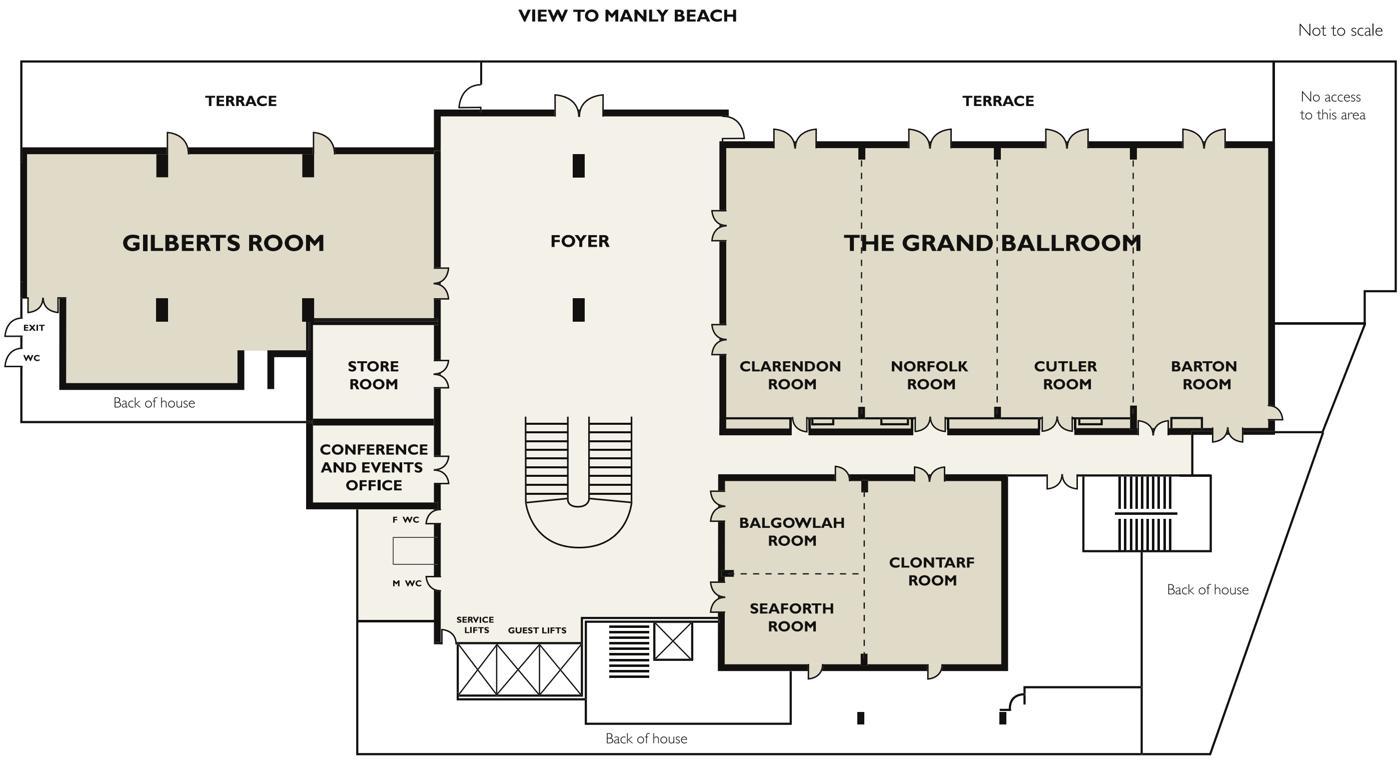

MANLY AREA MAP

AAEE-2017 Proceedings

Aboriginal Engineering for an enduring civilisation

Cat Kutay, Elyssebeth Leigh
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SESSION C4: The role and impact of engineers and the engineering profession in the wider community

CONTEXT Engineering is a set of practices and principles evidenced in the artefacts of human cultures. In the 21st century there is growing understanding of the implications of this for supporting innovation and sustainable practices. This paper specifically considers how Aboriginal cultures employed engineering principles prior to European arrival. Taking into account this combination of engineering principles, this paper introduces the next steps towards a framework for integrating Indigenous knowledge into the engineering curriculum. The aim is to provide a guide for engineering educators towards establishing and/or strengthening their engagement with local community knowledge holders to explore the principles and practices as well as teaching strategies of Indigenous technical knowledge.

PURPOSE Provide guidance in what is involved in developing processes for integrating Aboriginal/Indigenous engineering knowledge into engineering education, including provision of resources to contribute to revising our knowledge of Australia's technological history.

APPROACH Various approaches are being used to integrate indigenous and non-Indigenous engineering knowledges. These include locally sourced projects and encouragement of Indigenous students to become engineers. Integration of indigenous knowledge, frameworks and protocols into engineering education is increasing our understanding of the impact of engineering designed for specific cultures and values. This work provides engineering educators with an exploration of Indigenous engineering practices in pre-European times; and introductory work on assisting collaborative efforts between communities and engineering educators through:

- exploring how engineering education might be enhanced by incorporating knowledge about the civilisation occupying this continent prior to European arrival
- identifying sources of evidence for Aboriginal engineering, and relating this to engineering education to develop cultural sensitivity and sustainability knowledge in engineering education
- considering how such evidence as located in artefacts, concepts and physical contexts, can be used to expand the scope of engineering education programs across different disciplines

RESULTS These include protocols for engagement with Indigenous communities and suggestions for understanding Indigenous knowledge relating to Engineering and IT topics. We are in the process of developing an app to provide information to universities using location-based information. We also envisage this may also help tourist groups wishing to study aspects of indigenous knowledge and technology.

CONCLUSIONS Indigenous and non-indigenous engineering have many features in common, but until recently Indigenous knowledge has been ignored or denigrated. Developing ways to link awareness of similarities across engineering practices will provide practical and enjoyable experiences for students and educators, enabling them to expand their awareness of issues concerning sustainability, communication and cultural understanding in a diverse world.

Keywords Indigenous engineering, Sustainability, Community projects

Introduction

The tasks involved in integrating Indigenous engineering knowledge into engineering education are slowly being developed in a number of contexts: In-community projects; case studies in class; and indigenous approaches in teaching. Also the process of engaging Indigenous people in engineering studies includes: establishing scholarships for Aboriginal students; collecting archival and research material re-examining our knowledge of Australia's technological history; and exploration of protocols to connect with local communities on the basis of sharing knowledge as equals.

In particular the latter activity is integrating indigenous and non-Indigenous engineering knowledges, including locally sourced projects and encouragement of Indigenous students to become engineers. Such projects build on community collaboration, while also introducing and developing the concept of appropriate technologies. Integration of indigenous knowledge, frameworks and protocols into engineering is providing an opportunity to examine the impacts of engineering artefacts on various social and environmental conditions for which they were not designed.

The aim of the enduring Engineering project is to support engineers acquiring knowledge of Indigenous technology ether at university or through further study, with an app-based resource. This will, over time, link to indigenous community stories, records of local engineering knowledge, exploration of Indigenous engineering practices in pre-European times, and a framework for assisting collaborative efforts between communities, engineers and educators.

Background and Motivation

It is a troubling fact that many Australian government policies are based on a deficit view of Aboriginal civilisation, such as 'Closing the Gap' and the BasicCard to remove the control of finances. A direct impact of such positioning is to ignore the depth and scope of knowledge and capabilities embedded in the fabric of Aboriginal society and culture. This denies the longevity and complexity of the engineering history of Australia. Rather than considering knowledge as an opportunity for equal exchange and a meeting of minds, the deficit model is rooted in a belief that cultures occur as a hierarchy positioning some cultures as innately superior to others. Thus researchers position indigenous people as less than themselves (Craven et al, 2016) or than societies which developed the use of metals(Powell, 2008)

To redress the errors of such a belief involves establishing more valid method of engagement with Aboriginal knowledges. We consider in this paper some examples of what can be learned by adding Aboriginal perspectives to teaching and designing within the discipline of engineering. Valuing Aboriginal perspectives, and replacing out-dated perceptions of cultural inequity with a deeply respectful curiosity, positions Aboriginal knowledges as equal with, and simultaneously different from, other engineering knowledges, based on the observational processes used in knowledge gathering (Kutay, 2017).

Enacting this changed perspective helps to reveal that a key cause of the perception informing that deficit view, is a lack of knowledge exchange between Aboriginal and non-Aboriginal cultures. It resides in a general ignorance of Aboriginal beliefs and values, as well as a widespread lack of understanding of the practices, knowledges and principles underlying Aboriginal Australia's enduring civilization (Pascoe 2014, Gammage, 2011). One way to change this limiting perspective is to acknowledge the omission of Aboriginal engineering knowledge from current teaching practices, alongside the comparative absence of Aboriginal and Torres Strait Islander students from Engineering classrooms. One method for achieving sustained change in perspectives will be well informed learning strategies. It is clear that 17th century Aboriginal engineering knowledge paralleled the engineering known to Europeans in 1770, and that it was practiced across the entire continent in diverse, yet fundamentally similar, ways.

Enduring Engineering

What is now better understand is that when members of one culture are witnessing another culture in action, their interpretation of the actor's culture will be based on assumptions embedded in the observer's own culture. There can be no neutral analysis of what is being observed. It is in the moment of interpretation, when an author begins to interpret their observations, that tacit assumptions about superiority/inferiority begin to taint the description. Consider Pascoe's (p17, 2014) use of the following passage, written by a European observer in the late 1800's:

> *As soon as the water began to run back to the river the blacks used to make a fence across these channels of thin sticks stuck upright, and close enough to prevent the fish going through, but leaving a space at one side, however, so that when the fish found they could not get through the fence, they naturally made for the opening. A black would sit near the opening and just behind him a tough stick about ten feet long was stuck in the ground with the thick end down. To the thin end of this rod was attached a line with a noose at the other end; a wooden peg was fixed under the water at the opening in the fence to which this noose was caught, and when the fish made a dart to go through the opening he was caught by the gills, his force undid the loop from the peg, and the spring of the stick threw the fish over the head of the black, who would then in a most lazy manner reach back his hand, undo the fish, and set the loop again on the peg.*
>
> *I have often heard of the indolence of the blacks and soon came to the conclusion after watching a blackfellow catch fish in such a lazy way, that what I had heard was perfectly true*

In the 21st century more observant and enlightened thinking reveals the range of engineering concepts in action in what is being described. However the assumptions of this observer, presented here as accepted truth, demonstrate the absence of any comprehension of engineering principles. The constant repetition of such ideas helps explain the absence of more relevant and explicit records about, and respect for, Aboriginal engineering in Australian history.

Another, equally compelling reason for the low level of recognition of Aboriginal knowledges of engineering lies in the hardship facing Aboriginal communities in the face of loss of access to their country. Over time the knowledge went underground, and knowledge holders, those surviving disease or conflict, found it harder to ensure that what they knew could be safely passed on to future generations. People found many different ways of avoiding the demise of their vital knowledges (Skuthorpe and Sveiby, 2006), as Aboriginal Australia was a knowledge society long before the west recognised such a concept.

Available artefacts demonstrate clearly that the knowledge held in custody by generations of Aboriginal engineers was diverse, extensive and detailed. It was appropriate to the land and to the social structure and principles of the knowledge holders. Social and environmental conditions in Australia have changed with European settlement but this knowledge still can be applied as it is rooted in a deep understanding of how this country works. For instance when carp took over the Murray-Darling basin, it was Aborignal people who proposed the fish could be used as fertiliser (Duncan, 2017, pers. comm. October 6 2017)

Equal representation of ways of knowing

Bringing this enduring knowledge to general consciousness and achieving acceptance is clearly going to be a complex process. This paper is considering implications, suggested by the research summarised in Figure 1, of the overlapping segments in the Venn diagram, within which knowledge is common to various components. For example the overlap between the two forms of engineering - Aboriginal and Western (dominant) - proposes a shared set of relationships in regard to engineering principles and practices. Both forms of engineering created buildings, constructed roads, excavating mines (DPI, 2007) and all the other visible and conceptual outcomes of technical processes that we employ, occupy and see around us today. While Western engineering examples are readily identifiable, Aboriginal engineered buildings, structures, transport routes and processes, designed on the principle of sufficiency and collective processes, are similar in function while quite unlike the products of Western thinking.

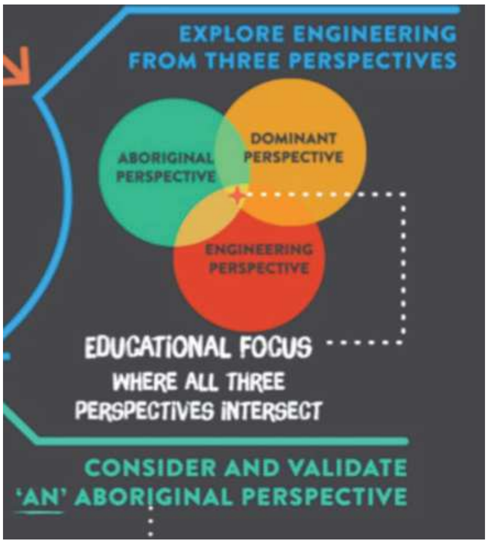

Figure 1 Aboriginal and non-Aboriginal knowledge intersect with engineering. Leigh et al 2015.

All human societies emerge from specific constructs having their roots in beliefs and values which created cultures and behavioural frameworks of immense variety and specificity. While conventional Australian history tells us a great deal about western principles and practices there is much less written about Aboriginal history and even less about the engineering. We are identifying and explicating Aboriginal engineering knowledge, to understand how this can have a minimal impact on both land and people at all times.

Representing this way of knowing, is not simple given the current broad social expectation that individuals can own and control property without any consideration of the long term effects on the surroundings. Consider, for example, the loss of water flow in the Snowy River and consequent damage to the land east of the dividing Range; and the current controversy and bitterness over efforts to manage the Murray-Darling basin to satisfy land owners who have different needs and priorities along the course of those rivers.

Knowledge Sharing Process

For student groups to work with community to design technology, we need to consider knowledge sharing processes and the kinds of engagement that is appropriate. If we want to share technology with Aboriginal people, we have to share the knowledge with the culture that is embedded (Mesthene, 1969). Either we are asking the community to enter the culture that created the technology, or we use engagement in design to change that technology to suit the culture. The first route involves assimilation and implies that cultural hierarchy of deficits of knowledge. The second route supports embedding of cultural knowledge in the new technology, and as the knowledge becomes part of the artefact, so will Aboriginal people begin to feel affinity with the product.

The protocols of knowledge sharing arise from the relationship between the researcher and the community. The procedures used in Aboriginal oral knowledge sharing reduce the potential for incorrect information being inserted into stories. The western concept of open format sharing of mainstream knowledge, too often creates the experience of invalid information being shared. Conversely, in functioning Aboriginal societies, information that should be private will not be shared publicly, and information that belongs to one person is rarely shared by another as claims of authority must be substantiated.

We need to understand the nature of traditional culture and how its processes remain relevant to today's values. To introduce students to this culture requires consideration of how and why processes will differ. What was each/any culture aiming to preserve and to create within the scope of its civilisation, and what is its understanding of the social and physical environment and how to live in it?

Aboriginal culture is based on an observational approach to science which makes full use of intuition and 'gut feeling' to gather information and understand the world. We consider how did such a knowledge gathering process maintains its integrity and what influenced and shapes those processes such that they remained constant and consistent, not changing at the whim of someone's vision or personal experience. That is, what ensured that the great range of such stories was worked into a coherent whole. Understanding these processes are crucial to understanding Aboriginal knowledge and how it is shared

What knowledge is valued

If western science tried to explain fire, the ripples and motion, where it will travel at any time, how much it will burn, how hot it will get, this would involve more non-linear equations than our present computer power could manage. An approach which operates by breaking science down into component parts and then build this up again into models of the whole system, tends to loose the picture of how things work. Use of the metaphors of clockwork mechanisms versus living organisms can help to explain the distinction between western and Aboriginal engineering.

When confronted with a complex problem, western trained engineers will approximate, reduce the variables, simplify the equations. The aim of such a process is to extract the patterns in the system, identify the main features and map how things generally interact. It in in this pattern matching that we start to approach the holistic methods used by Aboriginal teaching. This approach integrates sustainability from the start of any design or project (Kutay, 2017). If something is to be altered in any major way, the stories and knowledge sharing practises allow a long term consideration of consequences for everything involved, the people, land, flora and fauna.

Clearly if an Aboriginal approach had been applied to consideration of building coal-fired power stations in Australia, the outcome would have focused on developing clean energy and the present crisis in energy generation could well have been avoided. Aboriginal engineering values working with nature, the environment and the people.

How knowledge is taught

Aboriginal people used song cycles to provide contexts within which to remember and reinforce the knowledge that needs to be told in community meetings. Hence when sharing knowledge a very general moral story can be used for a context in perpetuity, but the individual aspects and histories that are provided within this theme will be those that apply to the present situation (e.g. the season) or the topic chosen (e.g. history at one place). These stories also retain a link to narratives that are not relevant in the present context, but will have to be re-told in the future as conditions change. By using existing Aboriginal stories and relating them to modern themes within the projects being developed with students, we provide more relevance to the information shared (Bodkin-Andrews et al, 2015).

When and by whom can knowledge be shared

In many Aboriginal languages there are 4th or 5th person pronouns, so if I talk about what we (you and I did) that is a different authority to talking about what we did (myself and someone else) or they did (when I did not witness). It is a way of expressing authority over the knowledge given. So when this knowledge comes over the internet, or on an app, whose is it and what is the relation to the source? The experience of Aborignal people online questions a lot of our assumptions about knowledge curation.

Who owns the knowledge

Aboriginal culture is based on relationships, to talk to someone you have to establish how you relate to them first. When you have a place in the knowledge network, the stories that relate to this position, such as relating to your totem, can be shared with you, while other stories cannot be shared, since you are not positioned to be a recipient. This is a form of 'need to know' sharing, that ensures that information is not misinterpreted.

What will be told to you

Technology co-design activities with communities require knowledge be passed on to researchers. The experience in developing these projects with community has been that researchers would be told information based on what they able to understand. However, sometimes they would be also be told information simply because this provides an opportunity for its preservation, by passing it on to someone outside the community with no responsibility and links to the community, allow it to survive until the people are ready again to use it.

However, in general, sharing knowledge openly for all time is not considered suitable, and yet this is how modern teaching methods operate, meaning that information could be shared without assuring that pre-requisites have been covered. This is a concern not only in relation to Intellectual Property issues and Open Data, but also in relation to having a suitable process for sharing that also preserves the integrity of the knowledge.

How will knowledge come

An understanding of matters relating to a culture other than one's own, comes through experience, and through listening, which takes time. Asking a question can imply a demand to access knowledge that you may not be ready for, or lead to a person answering risking error by giving an incorrect/inadequate answer to another's question.

This process is understandable in light of the fact that traditional societies could not afford to have knowledge holders make errors - food could be missed when throwing a spear or lives lost when navigating to a new area. There is great shame attached to failures of knowledge application. Trust comes when these points are respected by researchers.

Protocols

There are existing protocols for research in Aboriginal knowledge (AIATSIS 2012), and the fair and equitable sharing of benefits arising from the utilization of genetic resources (Biological Protocol, 2016), These are especially relevant to knowledge sharing where the financial benefits of innovation are still unknown.

Before starting a research project with Aboriginal or Torres Strait Islander organisations, there are important issues to consider.. The process of creation of a product is as important as the final product (see Leigh et al, 2015). Research conducted at Wollongong University as part of an OLT grant developed and documented clear ideas about how to conceive of, and plan for, cross-cultural work with Aboriginal communities (Goldfinch et al. 2016)

The 5Rights© protocols include the need to find and develop contacts with the *Right People* in the community who can inform and champion the project without becoming overworked by these demands. These people must be from the *Right Place*, that is their country must include the place where the project is based, so that they have authority to speak about it. Then there is use of the *Right Language* to avoid offence and convey respect for the importance of oral history and the perspectives of the community. Then there is the *Right Time* as having a community understand the relative importance of new issues that arise take longer than planned, while other commitments can slow progress. Finally the *Right Way* involves incorporating these previous four ideas into a relevant, and appropriately scoped, project design and implementation plan.

To start this process we also need to prepare academics for teaching the new material in terms of the experiential, cognitive, affective and conative components of their attitudes to Indigenous knowledges and cultures (see Goldfinch et al 2017).

Findings for Future Work

We provide here examples of projects to engage with traditional technology and modern applications of traditional concepts. These projects have developed out of training engineers at university and in organisations.

Water engineering

The existing engineering artefacts around fish traps both on rivers (eg Budj Bim and Brewarrina) and on the ocean (eg Mystery Bay presented by Uncle Max Harrison, 2017) provide a physical experience of the vastness of the canals and rock constructions that were developed thousands of years ago in Australia. Information on these sites will be available on the Enduring Engineering mobile app with links to the community members who can speak on how the traps work. This process allows engineers and the general populace to understand how the structures functioned and link this with present engineering understanding of water and construction techniques. However there are many resources needed in the early research, rejuvenation and reconstruction phase of these sites. For these the local community should be included to ensure the knowledge is strengthened locally.

Construction

Sandon Point in the Illawarra region of NSW, is the site of an on-going protest against development on sacred land. The University of Wollongong ran a project with student engineers, who consulted with the community and developed designs for a number of relevant site needs including an artefact storage space that respected the people's request not to break the ground. The community is concerned about damage being done to the environment and the storage of artefacts that are being uncovered in the area.

The Illawarra Lands Council is now working with the University to consider designs for future development on the lands they own in the area. Engineers Without Borders is being approached to provide a resource to link these projects with students at University to ensure that the correct protocols are managed and that students are prepared for and supported during these projects.

Sustainability

Through the support of the Royal Society of the Arts (Australia and New Zealand) a workshop was held at Ausgrid with Benjamin Lange, an Aboriginal Engineer whose research into the acoustics of the didgeridoo has been used to expand knowledge of the vocal tract. The workshop explained the type of Aboriginal knowledge that existed before invasion and how this could be used by Ausgrid to deal with their community liaison issues in the present.

These talks are part of an ongoing series that the RSA A+NZ are running to raise community awareness of the engineering aspects and allow community knowledge holders to present to a wider audience. It is hoped that this support can be extended to a community run on-site exploration of a specific fish traps site, to both explore what might be found out about the site, and to develop repeatable processes for conducting future research projects.

IT development

At UTS software development workshop, students have been engaged in developing software for Aboriginal clients and for providing resources for students learning about Aboriginal Engineering. The apps are designed as a point of contact to link community experts with interested students or academics to share these projects through traditional forms of knowledge sharing. Tourists can also search for places to go for traditional knowledge. The development process has involved students in discussion with clients about the history of the knowledge, why the apps are now being developed, the market focus for such products and the social aspects relating to their use.

There are also various indigenous led IT projects such as the Indigital App which integrates digital technology and art by enabling users to scan an art work and link to videos etc. about the artist and the story of the art work allowing storytellers to reach a wider audience.

Conclusion

Indigenous and non-Indigenous engineering have many features in common, but until recently Indigenous knowledge about engineering has been ignored or denigrated. Developing ways to link awareness of similarities across engineering practices will provide practical and enjoyable experiences for students and educators, enabling them to expand their awareness of issues concerning sustainability, communication and cultural understanding in a diverse world.

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Flipped Learning not Flopped Learning

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SESSION C1: Integration of theory and practice in the learning and teaching process

Context Introducing Flipped Learning across the University of Technology Sydney (UTS) was trialled through the Faculty of Engineering and IT (FEIT). It raised concerns on how to implement such a teaching program in skill-based subjects that had strong elements of core competencies centred on communication, understanding and critical analysis. Rather than revert to conventional teaching when half a class fails to prepare, an alternative approach for motivating students to read and study the material was needed. We had to demonstrate to students an advantage in preparing for class if active engagement was to take place. This may include peer assessing of each other's work, presentations by expert staff on alternative perspectives, or application of the content being taught beyond the assessable items

Purpose In order to encourage intrinsic motivation in study we wish to allow students to manage their own study and engage with material in their own time. This experience will increase their confidence to approach problems themselves if they receive timely feedback. One of the aspects of Flipped Learning that academics consider the most difficult is to enforce preparation for class work. We describe here some more conducive approaches to encourage students to engage with preparation material, including pre-submitting work for sharing in the tutorial. We provide some case studies of strategies, from those doing face-to-face courses ,to engage their students. We wish to show that there are a variety of ways to provide this added benefit for students,

Approach The paper provides case studies from approaches that have been shared amongst staff during staff development workshops run by Teaching and Learning in FEIT at the UTS. Some strategies to engage students who have prepared for a class, and hence provide intrinsic motivation for preparation, are:

1. Provide immediate feedback as they go through the preparation material; e.g. a quiz designed to cement concepts learnt in the lectures provided before the class.
2. Provide practical examples for the student to undertake and upload online a report. Students use this material to peer assess each other using an assessment rubric also online. This process allows them to engage with the rubric to learn how it applies to such a submission as well as engage in group discussion with their peer about their work.
3. Present material from a different perspective that is not part of the course, but bonus work, such as stories of the use of the skill in the workplace, an alternative use of the theory in another sector not related to course, and so on.
4. Develop a narrative approach where the experience of the lecturer in industry is used to make the material more engaging, and where the industry in this case can be cross cultural experience such as Aboriginal community infrastructure and appropriate technology.

Results In the first and second example, the changes to the preparation strategy has achieved a nearly 20% increase in success rate on a significant assessment, the writing of a resume to fit industry standards and ensure students achieve an internship job. The third examples has provided mixed students feedback partially due to different student learning expectations.

Keywords: Flipped learning, Student activities, Student engagement

Introduction

From a teaching perspective, flipped learning provides the time and space within the conventional university class format to allow active learning. It is supported by research that indicates students can experience significant learning gains compared to passive lectures (Freeman et al., 2014; Biggs, 1999; Pathen & Schunn, 2015). However, functional implementation for staff is often challenging particularly when it comes to encouraging student preparation for, and participation in, class. We describe, through examples, conducive approaches trialled to encourage student engagement with preparation material, including pre-submitting work for sharing in the class.

The first course examined here is preparing students for their work internship, a process the university guides them through with various modules. It is highly vocationally oriented to reflect practical engagement with industry and will therefore change as the nature of the internships available changes, reflecting changes in industry. Changes to the preparation strategy have achieved an increase in success rate on a significant assessment: the writing of a resume to fit industry standards and ensure students achieve an internship job.

The second course is a Transmission Systems subject recently taken over by Canning. This is a postgraduate course for International Masters students the majority of whose primary motivations are to access Australian residency and employment. The third example is a series of modules being developed to integrate into different subjects and provide a new perspective on the course content.

There are a variety of ways to engage students with the material that provides added benefit for them and engage the lecturer or students in more in-depth explanations to avoid forced learning. Some are more intensive to implement than others and an assessment of their value is necessary. This paper looks at the four strategies listed above and some results supporting these changes are provided. However, the model chosen by lectures will often match their preferred teaching strategies, hence a range of options with their motivations is discussed.

Background

There are various issues to deal with when teaching Engineering and IT. We are dealing with a cohort of students from many countries, sometimes mature age with experience in industry, often working full time and those who grew up with online learning. At UTS, these learning issues have influenced the implementation of flipped learning, and the approaches taken in different courses.

With flipping, classroom lecturers are often simply providing a static method of knowledge transmission via videos that have to be updated regularly and cannot be tailored to the individuals. However, we have added to this process other tools such as peer review prior to classes and it is in the classroom that we can provide active learning and motivate a diversity of students. This diversity can create challenges.

Motivation of International Cohort

To undertake the courses, the students often pay significant fees and sometimes work more than 20 hours per week. It is evident that many are struggling with the workload with one student falling asleep during laboratory work raising sifnificant OHS concerns. The strong connection with political and economic migration make Australian international students prone to the vagaries of immigration policy. Other reasons that enhance challenges include sometimes lower standards of preparation from their home institution, lack of support to transition from face-to-face teaching to online learning (Kember, 2000), including a feeling of isolation, low communication skills in English, a lack of genuine independence of learning strategies, and a focus almost exclusively on employment outcomes.

The success of future teaching will rely more on tailored and customized adaption of courses to students, particularly moving towards individualised and active learning becomes more popular. This will need to focus on the difference in motivation towards competition or achieving as an important dimension for Australian students, and an equally potent motivating factor for Asian students of social approval and intrinsic factors (Niles, 1995). To cater for group differences we need to rely on providing a variety of activities and assessment.

It is worth noting that the motivation for overseas students have been researched and can be quite unlike the stereotypes, as for Hong Kong students:

> "Courses which provide good career preparation are a source of motivation but it is not an extrinsic form of motivation which depresses intrinsic motivation. There are high levels of achieving motive, but it frequently has a collective nature rather than being individual and competitive" (p. 99 Kember, 2000)

Learning Strategies across Cultures

What we need to consider is the instructional and environmental preferences of students and what are the range of styles we need to cater for in course design. Rather than try and classify our students each session, we would benefit more from catering for the expected range of learning strategies we might have in the class, and encourage students to broaden their strategies. While Hofstede's (1986) work has been criticised for over-simplifying, to provide some idea of the options for cultural variation around teaching and learning, we can use his dimensions to look at activities that suit students from different cultures:

- the effectiveness of group learning and how to structure these (collectivism);
- forms of questioning in instructional groups (uncertainty avoidance);
- the expected authority, knowledge and role of the instructor (power distance);
- the use of academic or plain and emotive language by the instructor (femininity); and
- the use of praise by the instructor (indulgence).

By varying these we can provide activities that suit different student's learning approaches. We give examples of subject themes under these topics under strategies below.

Flipped for Engineering and IT

Concern over the practise of flipping the classroom has often arisen from the approach of transferring the lectures to videos to view at home as a substitute for a live teacher's instruction, which is not considered useful (Bernard, 2015). However, there are advantages in this approach in overcoming imbalances arising within traditional teaching. Students at the back of the lecture theatre will not be as active or engaged as students at the front and different personalities interact more (Freeman et al., 2014; Stumm & Furnham, 2012). This imbalance results in approaches to learning that directly correlate with the undergraduate students performance at graduation (Chamorro-Premuzic & Furnham, 2009). Further, videos provide the option of repeated watching to overcome the short time span focus of most students in lectures.

Flipped learning ultimately has to also deal with competing online courses. A motivated student can possibly learn a university level course outside of the university system. Notably, the emphasis on continuing education for life is increasingly adopted by professional employees as a way to stay ahead of technological change. Flipped learning buys into the online aspect of such learning and needs to provide added incentives and engagements for students to ensure they benefit from the online material and learn to motivate themselves.

In skill-based courses knowledge content does need to be presented before the class in such lectures. However, a flipped classroom requires a strategy to integrate collaborative group activities and meaningful, online individual instruction (Zappe *et al.*, 2009). Some lecturers provide assigned readings before class and offer incentives (e.g. quizzes with bonus points) to encourage student to complete pre-work (Bates & Galloway, 2012). The difficulty is that, as Love *et al.* (2014) concluded, "There is no single model for implementing the flipped classroom approach, … and our review of the literature indicates that the approach is still in a stage of innovation" (p. 319). The most dramatic impact of online teaching that reflects this niche class approach is the swelling of preparation times required to continually adapt and monitor these flipped courses.

Strategies

The aim of this paper is to provide clear examples of strategies used at FEIT in the UTS across various Engineering programs with some outcomes in terms of students' results or feedback. These examples highlight particular challenges and can assist those teachers who wish to innovate in their subjects. It is an attempt to put into a greater context the notion of flipped learning. We look at providing: feedback to students working on pre-class material; encouraging student verbal interaction through peer review; providing alternative applications of the skill in class to extend the pre-work; posing questions for post-work that encourage non-verbal students to engage more; and narrative teaching to help students develop a cultural context for their learning

Assessing the Flipped – the role of quiz

Providing online content before class means many students work alone whilst a small cohort may work together. There are limited options for synchronous feedback to address this, so self-assessment through quizzes highlight the significant concepts covered in the lecture. Students begin thinking about the material as well as receive feedback on understanding concepts but there are concerns that this process is isolating and unsettling for many students. It can be partly addressed through group activities. For Transmission Systems, group quizzes and peer assessment follow individual quizzes.

Quizzes can begin the lengthy process of teaching personal responsibility, offering a gauge for students and their peers to monitor against. Working with others teaches team work and communication, in turn demanding responsibility from all group members. A group variant of traditional paper quizzes is now being done for students online.

In class peer review

Research (Patchan and Schunn, 2015) shows peer review of other's submitted work has been fundamental to growth, taking assessment out of the hands of (often casual) teachers and putting it back in the hands of the students. Peer review has the advantage of generating student interactions, and providing an opportunity to quantify and teach teamwork. Learning grows from relative assessment against one's peers,

The context of peer review learning was described previously (Figueroa *et al.*, 2014). The subject focuses on preparation for industrial work through learning about transferrable skills such as communication, ethics, OH&S, industrial relations and dive. Students attend tutorials of up to 20 students to discuss and compare their work. A repeated theme of each tutorial is students learning through reflection.

Rust et al. (2005) describe the process of peer review which can be used to enable students to construct their own understanding of the assessment criteria, helping to understand what they and the instructor is aiming to achieve in their reports. The activities in the tutorial help develop a common understanding of the rubric enabling the students to develop their own professional and relative assessment of their work. The tutorial process involves:

1. Introducing the concept of professional self-assessment and the exercises enabling this,
2. Have them pre-submit the work and in the tutorial those who have not done so sit out,
3. Provide the rubric and set up groups of pairs to assess each other's work,

4. Mark the students' work that is submitted after rework based on peer feedback to provide further reinforcement of the rubric approach.

In the results section, we will discuss the benchmarking exercise and its results in assessing improvements in the students' learning.

Tutors need to be strongly engaged in this process so that they are sufficiently prepared on the material to use it without reverting to repeat-teaching it in class. To manage the course, the mostly casual tutors are trained in a similar manner to students. After marking some samples, the subject coordinator meets with tutors to discuss the marks and/or sections that differ greatly. The rubric is reworded to match what the tutors and course coordinator understanding of the words until a near-shared meaning is achieved. This results in the spread in marks on each test assignment across an acceptable level, clearly an exhaustive process if it is to be successful.

A second example was carried out in Transmission Systems. This subject allows students to engage with the rubric to learn how it applies to a submission as well as engage in group discussion with their peers about their work, developing a shared understanding of the task.

Redo the content in a new format or context

Much of the aim of this teaching method is to inspire students to use critical thinking to see beyond economic drivers to the wonders of science, engineering and technology. This aspect of what is essentially research intensive thinking is becoming fundamentally essential in the workplace and needs to be reinstated as a primary objective of any teaching. The Transmission Systems subject is particularly amenable because transmission systems hardware and signal processing are underpinning societal change in the way communications is viewed and in the way the community will function. For example in one tutorial, we highlighted the internet of things (IoT), where a consumer fridge could have many sensors monitored online. This emphasised how much we rely on core transmission systems as well as highlighted how end-user directions will shape the next generation technologies.

Although purely introductory and not put into the online lectures, the aim was to point out that the course lectures are a comprehensive backbone that remains essentially relevant in the new language of IoT, where many graduates will be expected to be participating in, not simply in traditional telecommunications jobs. This opens up the student to a new landscape in employment opportunities. We feel this opportunity to contemporize the course in the tutorials without sacrificing the solid online foundations is a critical step to motivating students and to demonstrate that the future may not be the simple economic one they began with.

We introduce scholarly pursuit to students as driving deeper technological solutions, more so than economic factors. Examples are:

- When discussing noise in transmission, the online content was about the reduction of noise in signals. The face-to-face discussion was opened with instead sensing noise: noise external to the fibre is registered as distortion in the signal reflection as the features of the fibre material changes. Hence, noise analysis from the fibre can be used to extract voice and other signals from the area around the fibre, a potential cyber security concern.
- To demonstrate the expansive nature of the IoT, several novel examples were provided. One example was an experiment Canning was involved in, where in-line optical fibre filters (known as fibre Bragg gratings) were used to monitor strain in the hooves of a competitive Brazilian Creole horse and through an optical fibre cable the data uploaded as the horse was put under standard training with a professional trainer. The training rope was replaced with an industrial optical fibre cable collecting the data from the sensors onto computer and online in the farm (Martelli *et al*. 2017). What was found was that the horse trotting was synchronised with the heart rate of the horse. The compressible hooves were acting as a distributed heart for the horse effectively giving the horse a five heart organ and any misalignment of synchronisation can trigger arrhythmia. From the transmitted data an equivalent cardiogram was possible to extract.

- The growing dominance of photonics in transmission systems and the massive problem of latency, driven initially by gaming and other interactive activities and identified as looming challenge for ubiquitous sensing with the IoT. Given the speed of light is finite and ultimately sets an upper limit classical mitigation of latency, what will solve the coming latency roadblock as sensors are scaled through the internet? The students were asked to think about this problem based on what they have been studying, and when reaching an impasse, later the idea of quantum communications was introduced as the only viable solution at present.

Re-present knowledge with existential angst

The final example was developed at a previous university appointment by Kutay. The classes were activities around team formation, team building and scenarios not directly relating to, but supporting, the assessable work. The aim of the course was to provide a situation where the students are dealing with the required knowledge in a totally different cultural context,

The lecturer comes from a background of Appropriate Technology development in Aboriginal communities around Australia and has been involved in technical projects in urban, rural and remote areas. This has enabled them to understand how Aboriginal people relate to technology and engineering concepts, which makes for some interesting narratives for teaching and some confronting scenarios on the cultural bias in technology. The main aim of the course is to understand how culture and society effect an engineering design.

The series of topics can be considered in light of the first four Hofstede dimensions above as providing examples of cultural variation:

- Team development using an analogy with Aboriginal Kinship system of relationships
- Tacit knowledge sharing using story telling rather than the Socratic style
- Organisational governance and flat management where the learners are encouraged to manage the classroom
- Sustainability and scientific expression of concepts from an observational perspective

Some of the class time involves a lecturing format, but much of the time is student discussion of concepts relating to their experience so that students have an opportunity to unravel their own assumptions. We are expanding this work to modules that include assessment by video story telling and reflective journals.

Results

The aim of the paper is to provide some strategies for providing active learning for students, through flipping the classroom. However, the aim is also to verify the success of each strategy before recommending the approach to other lectures. The approach is to encourage critical thinking and analysis supported by enthusiasm and genuine interest, yet this is hard to assess. We can only assess changes in content learning outcomes within these new environments, or students expressed motivation.

Peer Reviews and Quizes

The work done on flipping the workplace preparation course involved flipping the lectures, running quizzes on these and providing in class peer review of student’s work. After reviewing the lecture material at home, the students were involved in peer discussion over their activities and used the analytical rubric themselves to assess others work. This ensures not only that the students read the rubric, but engage in active learning of the rubric concepts, enabling them to not only assess their own work before submission but consider why specific aspects are valued and what is being sought in the assessment. (Jackson & Larkin 2002).

The outcome of the new mode of learning, compared to the previous session’s subject (which was not flipped) was an 23% improvement in the initial assessment based on pre-study and quiz; and an 18% improvement based on learning from peer-review, with a satisfactory mark set at 11/20 for Resume 2. The rest of the cohort had to resubmit.

Table 1 Results for the Resume assessments across the two formats

	Pre-flipping		Post Flipping	
	Resume 1	Resume 2	Resume 1 after quiz	Resume 2
Total mark	/5	/20	/5	/20
No Students	218	222	124	122
Average	2.28	11.23	2.59	12
Std	0.91	3.63	1.05	3
Min	0	0	0	4
Max	5	19	5	17
No Satisfactory	84	135	77	96
% Satisfactory	39%	61%	62%	79%

Redo the content in a new format or context

The student open response to the feedback survey (SFS) results for the Transmission Systems subject are shown in Table 2. Reflecting the disparate variation in expectations for the flipped postgraduate course, are comments 7-6 and 7-8. These appear often and are probably unavoidable. They reflect the earlier discussion around the background of the students, many of whom were inadequately prepared for post-graduate study. It was for many their first exposure to online learning of this nature. Rather than simply being diametrically opposed, both comments clearly reflect a different level of maturity around learning responsibility. This tends to reflect that some aspects discussed in this paper did achieve some of the critical elements we aspire to in presenting such courses.

After a session of lectures where students were exposed to new topics and research in the area being discussed, we were delighted to see that in general the student feedback surveys were positive. The first comment 7-1 recognises the effort that was put in. We believe this is a fundamental re-evaluation of motivation and inspiration needed in all teaching.

Table 2: Results on Student Feedback Survey for Transmission Systems

7	What did you particularly like in this subject? 8 Open question 17.78
7-1	Most of the topics covered could be related to the real world applications. Professor helped us to think of what we study and how to apply innovative ideas to the existing technology. This is very important to me. Transforming what we have to something new would be great.
7-2	The content.
7-3	Overall good..however it may be better if subject focus on less content more deeply rather than more contents.
7-4	All the subject content is best and understandable videos make it simpler.
7-5	interest showed by the instructor during the tutorial sessions
7-6	I like the structure of the subject. The lecture videos is also great. There are very clear and not boring.
7-7	i liked the level of details in each chapter.
7-8	I don't like learning this subject just by watching the video.

Re-present knowledge with existential angst

The cross-cultural material was presented as part of larger subjects, to take a fresh perspective on relevant topics, and often the knowledge provided in class was not the assessable material, but simply a way to engage students more in the process or critique the approach proposed by the course content. The move to include Indigenous knowledge into the assessment across Engineering subjects will enable the class to engage more fully in cross cultural material relevant to their employment and engagement in Australian technological development.

Conclusion

A range of customising approaches to enhance student engagement in flipped classrooms has been analysed. Their applicability and success may depend on the lecturer or specific aspects of the student cohort, but the examples provide some evidence for the application of various novel approaches in teaching. These are examples where flipping the classroom gives the lecturer and the students much greater scope for learning concepts of knowledge creation, analysis, problem solving and cross-cultural understanding.

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A Study on Integrating Case-Based Learning into Engineering Curriculum

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SESSION: C1 Integration of theory and practice in the learning and teaching process

CONTEXT Republic Polytechnic in Singapore uses a range of lesson delivery pedagogies, namely: Problem-Based Learning, Interactive Seminar, Cognitive Apprenticeship and Project-Based Learning. Republic Polytechnic, School of Engineering has an interest in exploring methods to enhance students' learning in engineering modules. One idea is to explore the use of a topic-focused Case Study Paper that would span across a few lessons in an engineering module.

PURPOSE The purpose of the study is explore the usage of a Case Study Paper in a practical module for the school to enhance the student learning experience.

APPROACH This randomized experimental study involved engineering students who were taking Microcontroller Systems module in academic year 2016-2017 . A topic-focused Case Study Paper was added to the required student delivery of the module for this experimental study. A small group of 30 participants were randomly chosen from the cohort taking the module, and their Case Study Papers were analysed. The analysis performed were analysis using scoring rubric and Content analysis to categorize the students' work according to themes.

RESULTS Results from the scoring rubrics revealed that students needed help to improve on technical depth of the paper and clarity of presented diagrams. It also revealed students are good at transferring knowledge from other modules or from content learnt from Microcontroller Systems module to the Case Study Paper. Content analysis helped to answer these two questions:

- What are the applications that students proposed in their Case Study Paper that has a microcontroller?
- When students describe the applications, did they describe the major electronic components?

CONCLUSIONS While the results from the analysis of the Case Study Paper for the Microcontroller Systems module in this study has been quite positive, its effectiveness in improving students' learning is not conclusive due to the limitations of the study.

KEYWORDS Case-Based Learning, Case Study Method, STEM, Engineering Case Study.

Introduction

A polytechnic in Singapore adopts a range of pedagogies, namely: Problem-Based Learning (PBL), Interactive Seminar (IS), Cognitive Apprenticeship (CA) and Project-Based Learning (PjBL). The School of Engineering in the polytechnic has an interest in exploring methods to enhance students' learning in engineering modules. One idea is to explore the use of the Case Study Method that would span across a few lessons in a module.

Objectives of Study

The purpose of the study is to focus on exploring the usage of the Case Study Method in a hands-on practical module for the school to enhance the student learning experience. This randomized control trial study involved engineering students who were taking Microcontroller Systems module. A topic-focused Case Study Paper was added to the lesson plan of the module for this experimental study with institutional ethical approval.

Case studies are stories that are used as a teaching tool to show the application of a theory or concept to real situations. Cases can be fact-driven and deductive where there is a correct answer, or they can be context driven where multiple solutions are possible. Case studies have been widely used as a teaching tool in various disciplines and educational institutions. The use of case study method dates back to 1870, when Harvard Law School newly appointed dean, Christopher Columbus Langdell, introduced law-based case studies in the school. (Garvin, Sept-Oct 2003)

Methods

Participants of this study included second year students from the School of Engineering in the polytechnic in the academic year 2016–2017, taking the Microcontroller Systems module. This module was conducted using the polytechnic's Problem-Based Learning (PBL) pedagogy. Table 1 shows the typical daily routine for a student in the polytechnic using the Problem-Based Learning pedagogy. The starting time for the day's lesson for students of different years varies to avoid congestion in the canteens during break hours. There is an assigned lecturer and about 25 students per class. Individual students are required to submit a reflection at the end of each day's lesson, which is called a 'reflection journal' at the polytechnic.

However, in this experiment an assignment was added to write a Case Study Paper. The lecturer introduced the assignment to the students, and the topic for the paper was released in the first lesson in the Microcontroller Systems module. The students were to write the paper about an application of microcontroller(s) they had encountered in their daily life. The Case Study Paper included:

- Student's idea about the application
- Description and functionality of the system
- Input and Output(s) list
- Student's idea about a block diagram of the system

Scaffolding for this assignment was provided during the first four lessons of the module. Instructional scaffolding provides students with support to allow them to complete their tasks. Benson (1997) describes scaffolding as a bridge used to build upon what students already know to reach a new concept. Specifically, scaffolding came in the form of the reflection journals and guidance from the lecturer. For lessons one to three, there were specific reflection journal questions that helped students answer a part of the Case Study Paper. In lesson four, Learning Phase Three was used to help students finalize the Case Study Paper for submission.

Table 1: Lesson Routine in the Polytechnic's Problem-Based Learning Pedagogy

Duration within a session	Period	Description
60mins	Learning Phase 1	Students receive a problem as a trigger for learning. With the help of the lecturer, the students examine the problem and clarify what it is they know and do not know and formulate possible hypotheses. Each group identifies learning issues they will investigate. Groups employ research strategies to collect relevant information. Students collect different Information so that their knowledge may diverge at this point.[1]
45mins	Break	Lecturer leaves the class. Groups are on their own to continue to do their work or go for break.
90mins	Learning Phase 2	The groups of five meet individually with the lecturer to discuss their progress. Students continue in their group of five to review resource materials and peer teach what it is they have learnt from their research. Information convergence[2] should take place.
90mins	Study Period	Lecturer leaves the class. Groups are on their own to arrange for lunch break and prepare for presentation.
120mins	Learning Phase 3	Each team presents its findings to the other groups. Groups discuss, defend and justify their outcomes. Lecturer presents recommended answer to the problem.

Out of 164 students who submitted their Case Study Papers, 30 students were randomly selected for the study with their consent. Analysis was performed on these selected Case Study Papers. The analysis was separated into three parts:

- Analysis using scoring rubrics (Table 2)
- Content analysis to categorize the students' work according to themes
- Comparison of the quality of Case Study Paper to the quality of the reflection journals

The Valid Assessment of Learning in Undergraduate Education (VALUE) rubrics, developed by Association of American Colleges and Universities' (AAC&U) Liberal Education and America's Promise (LEAP) initiative, were referenced when creating the customized scoring rubrics in Table 2. Moskal (2000) states that by developing a pre-defined scheme for the evaluation process, the subjectivity involved in evaluating a student work product (she was discussing an essay, specifically) becomes more objective.

[1] From the Problem Statement, student work out what they know, what they do not know, and what they need to find out. The initial search for information is divergent and not all information will lead to the solution. This is encouraged in learning phase 1 to inculcate brainstorming and creative thinking.
[2] The lecturer work with each team to help them combine the information they had collected individually to lead to a possible solution for the problem of the day.

Table 2: Scoring Rubrics for Case Study Paper

CATEGORY	Excellent (4)	Very Good (3)	Satisfactory (2)	Weak (1)	Unsatisfactory (0)
Components of Case Study Paper	All required elements are present and additional elements that add to the report (e.g., thoughtful comments, graphics) have been added.	All required elements are present.	One required element is missing, but additional elements that add to the report (e.g., thoughtful comments, graphics) have been added.	Several required elements are missing.	All required elements are missing.
Amount of Information	All subtopics are addressed with at least 100 words each (except diagrams sections).	All subtopics are addressed with at least 80 words each (except diagrams sections).	All subtopics are addressed with at least 50 words each (except diagrams sections).	One or more subtopics are addressed with less than 50 words (except diagrams sections).	All subtopics are addressed with less than 50 words (except diagrams sections).
Quality of Information	Information clearly relates to the main topic. It includes three or more supporting details/examples.	Information clearly relates to the main topic. It provides at least two supporting details/examples.	Information clearly relates to the main topic. It provides at least one supporting detail/example.	Information clearly relates to the main topic. No supporting details/examples are given.	Information has little or nothing to do with the main topic.
Explanation of Application	Explanation is clear. There is technical depth in the explanation.	Explanation is clear.	Explanation is a little difficult to understand, but includes major components of the proposed application.	Explanation is difficult to understand and is missing several components of the proposed application.	No Explanation given.
Diagrams & Illustrations	Diagrams and illustrations are neat, accurate and add to the reader's understanding of the topic.	Diagrams and illustrations are accurate and add to the reader's understanding of the topic.	Diagrams and illustrations are accurate and sometimes add to the reader's understanding of the topic.	Diagrams and illustrations are not accurate OR do not add to the reader's understanding of the topic.	No diagram and illustration.
Application of Transfer	More than two clear applications of knowledge and skills from previous learning (from current module or from previous modules).	At least two clear applications of knowledge and skills from previous learning (from current module or from previous modules).	At least one clear application of knowledge and skills from previous learning (from current module or from previous modules).	At least one vague application of knowledge and skills from previous learning (from current module or from previous modules).	No application of knowledge and skills from previous learning.

As Tedds and Brady (2009) write one of the limitations of an analysis based on scoring rubrics is that it can be highly interpretive, making it difficult to generalize the results. Content analysis is performed for this study to address the limitation of scoring by using a rubric. Two questions that the content analysis can help to answer are:

- What are the applications that students proposed in their Case Study Paper that has a microcontroller?
- When students describe the applications, did they describe the significant electronic components?

To answer the first question, major categories of applications were identified and their occurrence counted. The answer to this question can help to identify what are the easier categories for students to propose. To answer the second question, significant electronic components were identified and their occurrence counted. Collectively, these data can help to identify gaps in what students should include in their application descriptions.

Because the reflection journal in lessons one to three are used to provide scaffolding for students to complete their Case Study Paper, we hypothesize: (1) the content of the journals and the Case Study Paper should not deviate too far, and (2) the quality of the Case Study Paper should be better than the quality of the journals. Lessons one and two journals are used for the comparison analysis. Lesson three journals were not used as they were done offline on paper and not submitted for analysis for this study.

Results

Using the scoring rubrics, the Case Study Papers of the 30 students were rated. For each student, the final rubric score was computed from the average scores of the six categories that composed the rubric. From those average scores, the mean, median, and standard deviation were computed based on the students' average scores and tabulated. The histogram in Figure 1 shows that the distribution closely resembles the bell curve, with a steeper slope on the right side of the mean. It can also be observed that the distribution is all on the right side of the graph, with lowest score being 1.83.

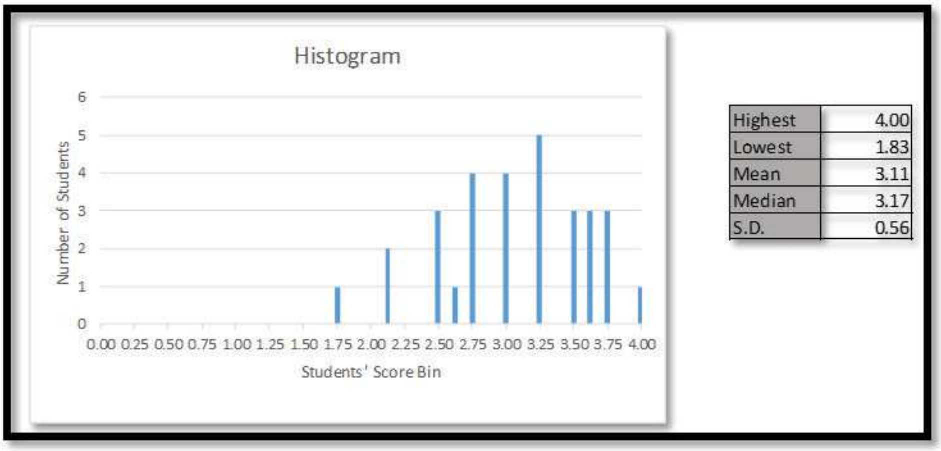

Figure 1: Histogram, Mean, Median, and S.D of Students' Average Scores

The mean score for each of the six rubrics category was computed and shown in Figure 2. The 'quality of information' category had the highest mean of 3.67, followed closely by the 'application of transfer' category and 'components' category with means of 3.6 and 3.5, respectively. The means for the 'explanation of application' category, as well as the 'diagrams and illustrations' category, are lower than the overall rubrics mean of 3.11, scoring 2.63 and 2.27 respectively. The students' average continual assessment grade is about 2.2 to 2.5 for Microcontroller Systems module. A rubric mean above this value can be considered as above average.

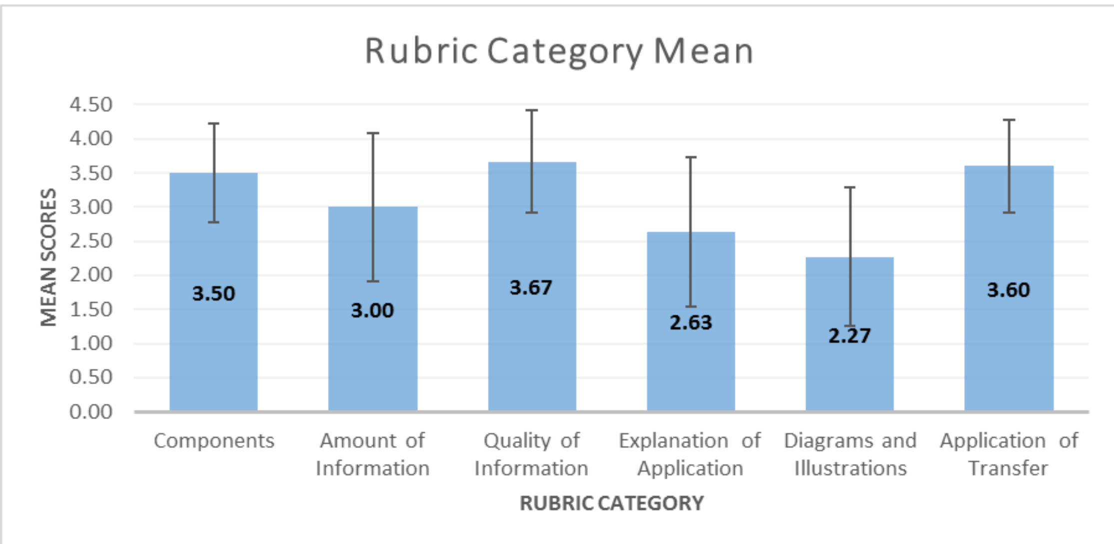

Figure 2: Students' Rubric Category Mean

Content analysis identified four types of applications the students wrote about: Household Equipment, Entertainment Devices, Office Equipment, and Miscellaneous. The distribution of the applications by categories is shown in Table 3. The application categories are mutually exclusive so there was a total of 30 applications.

Table 3: Student Identified Application Categories of the Case Study Paper Submissions

Categories	Occurrence
Household Equipment	15
Entertainment Devices	9
Office Equipment	2
Miscellaneous	4
Total	30

Further content analysis revealed that 29 out of 30 students described electronic components and wrote about their use. Among the electronics components mentioned in the papers, LEDs (Light Emitting Diodes), buttons, switches, keypads, sensors, buzzers and speakers were most prevalent. The applications proposed by the students are also examined to identify if these components should be included. LEDs should be included in 27 applications. Fourteen out of these 27 applications mentioned and described the use of LEDs. Buzzers and speakers should be included in 10 applications. All 10 of these applications described the use of buzzers and speakers. All 30 applications should include the description of buttons, switches or keypads, and 23 applications do mention and describe them. Sensors should be included in 25 applications, and 20 applications described them. The electric motor should be included in 19 applications, and it was included in 10 applications.

The students' Case Study Papers were compared to their reflection journals for lesson one and lesson two. The correlations between the reflection journals and the Case Study Paper were analyzed. The students would fall into one of the six mutually exclusive categories depending on how similar the entries in their reflection journals were to the sections of their Case Study Paper:

- Category One: Students with both lessons one and two reflection journals identical, almost identical, or identical subset (this means part of the RJ and the related section of the CSP contains exactly the same information in the same wordings.) to the application and system functionality description sections of their Case Study Paper.
- Category Two: Students with both lessons one and two reflection journals related to the application and system functionality description sections of their Case Study Paper.
- Category Three: Students with lesson one reflection journal related to the application section of their Case Study Paper and lesson two reflection journal identical, almost identical, or identical subset to the system functionality description section of their Case Study Paper.
- Category Four: Students with lesson one reflection journal identical, almost identical, or identical to the application section of their Case Study Paper, and lesson two reflection journal related to the system functionality description section of their Case Study Paper.
- Category Five: Students with lesson one not related to their Case Study Paper, and lesson two reflection journal related to the system functionality description section of their Case Study Paper.

- Category Six: Students with both lessons one and two reflection journal not related to their Case Study Paper.

Table 4 summarizes shows the number of students in each category when we correlate the similarity in quality of the entries in the reflection journals to the overall rubric scores on the Case Study Paper. For each category, the average rubric scores of all students in the category is shown.

Table 4: Summary of Six Categories Average CSP Rubric Score

	Average CSP Rubric Score	Number of Students
Category One	3.11	12
Category Two	2.93	10
Category Three	3.08	4
Category Four	3.67	1
Category Five	3.67	2
Category Six	3.33	1

Discussion

Referring to Figure 1, the overall scoring mean for the Case Study Paper is 3.11. This suggests that students performed above average for the Case Study Paper. Looking more deeply into the separate categories of the scoring rubrics, it can be observed that students performed better in some categories than in others. This analysis seems to suggest students are best at providing quality information and applying transfer of knowledge. Students are not very good at providing technical depth as reflected in the lower score for explanation of application category. The worst category is diagrams and illustrations category, which indicates that students need help to improve in this ability. One of the possible reason for the low mean score of 2.27 for this category is that the system functionality description and the block diagram were done in lessons two and three respectively. Most students probably did not visualize a block diagram in lesson two when explaining how their proposed application functions. In lesson three, these students probably did not refer back to their written functional description in lesson two while drawing the block diagram for their system. In lesson four, when the Case Study Paper is due for submission, a review to check for consistency between the system functional description and the block diagram was probably not done either.

The content analysis findings summarized in Table 3 revealed two major categories of applications described by students: Household Equipment and Entertainment Devices. This suggests that it is easy for students to relate to equipment commonly found in the home or systems used for entertainment as examples of microcontroller applications. This familiarity with certain types of equipment can be used to the instructor's advantage as he/she can discuss these applications in class, and the students will understand the reference. The content analysis findings also indicate that 29 out of 30 students described at least one electronic component in their papers. This shows that most students are able to apply prior knowledge and skills from the Microcontroller Systems module and from other modules like Engineering Design and Digital Electronics. Closer analysis indicated that while most students included buzzers in their applications, many omitted the LEDs, sensors, switches, or motors in their system. This suggests that we need to help students better understand the complexity of the systems we want them to be familiar with.

Referring to Table 4, it can be observed that Category One has a higher average rubric score compared to Category Two. This means that students whose reflection journals in both lessons one and two were identical, almost identical, or identical to the sections in those students' Case Study Paper performed better than students whose reflection journals were only somewhat related to the sections of their Case Study Paper. This suggests that the strategy of using what had been written in reflection journals to write complete sections of the Case Study Paper is an effective one, which can also help the instructor guide the students in writing a Case Study Paper. Although there were only four students in Categories Four, Five, and Six, we do note those students had higher averages than the students in Category One. This suggests that a few students are strengthening what they wrote in their reflection journals to develop sections of their Case Study Papers. We need to think about how instructors can further encourage this kind of improvement.

Limitations of the Study

While the study provides new insights into the use of the case study method for the polytechnic and other engineering schools, there are some unavoidable limitations of this study. First, as this is an individual thesis work, the Principal Investigator is the only analyst of the study. Having at least two people rate both the RJs and Case Study Papers would allow for inter-rater reliability, which strengthens the rigor of the findings. Second, due to time constraints, this study was conducted with only 30 randomly selected students from the cohort of students taking the Microcontroller Systems module. Lastly, the results of the Microcontroller Systems module examinations for the cohort of students who wrote the Case Study Paper should be compared to the exam scores of the cohort of students who did not do the Case Study Paper. This can help reveal if the Case Study Paper helped students improve their performance in the module. However, prior Microcontroller Systems module examinations do not have any questions related to Case Study Paper. While the Mid Term Assessment (MSA, similar to a mid-term exam) for this cohort includes a question related to the Case Study Paper, there is no comparison from past results.

Recommendations

This study has shown the Case Study Paper has promise as an assignment in the Microcontroller Systems module. However, the analysis in this study has helped to identify some issues with the implementation of the Case Study Paper. These issues, however, can be resolved with more stringent requirements and better facilitation in future implementations. Instructors implementing the Case Study Paper in the Microcontroller Systems module in the future should consider these recommendations:

- The assignment should add a requirement that emphasizes technical depth.
- The lecturer(s) should provide more guidance to students on how to produce papers with more technical depth.
- The lecturer(s) should provide more guidance to the students on drawing and explaining block diagrams.
- The students should be directed to use a platform (e.g., DrawIO) that allows for the standardization of the block diagrams.
- The lecturer(s) can recommend that the students use household equipment or entertainment devices for their applications since these seem easier for the students to comprehend.
- The lessons on the usage of LEDs in microcontroller applications should be reviewed to create a better awareness among students about how LEDs are used in micro controller applications.
- The usage of motors should be reviewed in the other engineering modules.

- The lecturer(s) should recommend the students use the RJs to scaffold complete sections of the Case Study Paper; this seems to result in better submissions.
- A full-day lesson should be implemented on writing the Case Study paper in the lesson the Case Study Paper is due. This would allow students more time to review, edit, and add information to their Case Study Paper. The lecturer(s) would also have more time for guiding students.
- The Case Study Paper should be implemented in later lessons in the Microcontroller Systems module instead of lessons one to four. All basic I/Os can be covered prior to the Case Study Paper, and students would be better equipped with microcontroller knowledge and skills.

Conclusion

While the results from the analysis of the Case Study Paper for the Microcontroller Systems module in this study has been positive, its effectiveness in improving students' learning is not conclusive due to the limitations of the study. More analyses should be done by a team. For now, it is recommended that the Case Study Paper be implemented for a few more runs in the Microcontroller Systems module to collect more data for future studies.

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Comparing Students and Practicing Engineers in Terms of How They Bound Their Knowledge

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CONTEXT

Research in conceptual understanding has shown that students are not developing the foundational knowledge necessary that will assist them later on in their academic and professional career. Additionally, when the knowledge is categorized as closely related to important and real problems, students are more likely to be motivated and have a greater ability to learn. Many educational problems are intentionally decontextualized, meaning that students are often learning in contexts that are not important or relatable to students which could influence how that knowledge is categorized. Understanding how students categorize knowledge can provide insight about their ability to apply knowledge in different contexts and how it impacts their preparation for engineering practice.

PURPOSE

The purpose of this paper is to compare how practicing engineers and students organize their knowledge into categories and realms of knowledge when working on or presented with an open-ended, multidisciplinary engineering problem.

APPROACH

Phenomenological interviews were conducted with 19 practicing engineers who worked on two different multi-disciplinary engineering projects. Practicing engineers were asked about their role in the project and their responsibilities. Semi-structured clinical interviews were conducted with 42 senior-level engineering students from a large university and a technical college. Sampling was conducted through email solicitations sent by the instructors of the senior-level courses. Engineering disciplines represented in the sample include Biological, Chemical, Civil, Computer, Electrical, Environmental, Embedded Systems, Industrial, Mechanical, Nuclear, Renewable Energy and Software engineering. During the interviews, students were presented with one of the real-world multidisciplinary engineering problems and were asked to discuss how they would complete a portion of the design that most closely related to their area of expertise.

RESULTS

Students were found to categorize knowledge differently compared to practicing engineers. A majority of the students referred to the interfaces between project roles as fixed and well-defined while practicing engineers spoke about these interfaces as dynamic and ill-defined.

CONCLUSIONS

The results presented here further emphasize the importance of utilizing real-world engineering examples to motivate students and assist them in developing foundational conceptual knowledge. Understanding how students categorize knowledge has provided insight into how differences between the contexts of engineering education and engineering practice could affect students' preparation to enter the workplace. Possible implications include what courses engineers are required to take and how to better design foundational courses such as physics and math to help students rehearse key skills and make connections to their own success as engineers so that key concepts relate to important and real-problems to help motivate students to learn.

KEYWORDS

Multidisciplinary, Categorization of Knowledge, Epistemology

Comparing Students and Practicing Engineers in Terms of How They Bound Their Knowledge

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Introduction

Research in conceptual understanding has shown that students are not developing the foundational knowledge necessary that will assist them later on in their academic and professional career (Hake 1998, Streveler, Litzinger, Miller, and Steif 2008, Streveler, Brown, Herman and Montfort 2014). But it is expected that students develop conceptual understanding as required by accreditation agencies (ABET, 2016; Engineers Australia, 2016). How and to what extent students are able to build fundamental and flexible knowledge that can be applied to a range of circumstances is dependent on how the knowledge is categorized (Bransford, Brown and Cocking 1999, Brown, Collins and Duguid 1989). Categorization of knowledge depends on the links students make between concepts and the circumstances in which they apply (Säljö 1999, diSessa 2002, Ivarsson, Schoultz and Säljö 2002). But research has shown that students often struggle with the actual categorization process (Chi and Roscoe 2002, Chi 2005). To alleviate this issue, researchers suggest that problems should be closely related to important and real problems to aid in categorization, increase motivation, and enhance the ability to learn. (Pintrich, Marx, and Boyle 1993, Sinatra 2005). Therefore, the research presented here utilizes real-world engineering problems to gain a better understanding of how students expect to categorize knowledge compared to practicing engineers. Understanding how students and practicing engineers categorize knowledge can provide insight about how they learn and how that learning impacts their preparation for engineering practice.

Purpose

The purpose of this paper is to better understand how students predict and engineers organize their knowledge into categories and realms of knowledge when discussing an open-ended, multidisciplinary engineering problem.

Methods

We identified and utilized two real-world engineering problems for our research with the assumption that meaning and knowledge is constructed through experiences. Selecting two real-world engineering problems occurred with the assistance of engineering faculty who teach senior design courses and drew upon their industry contacts. The problems had to meet the following criteria in order to be considered for our study: 1) an engineering project that involved multiple disciplines in which individuals worked across disciplines throughout the project, 2) represent different types of common engineering work, and 3) at least 3 engineers on the project willing to participate in a 50-minute interview. This resulted in the selection of two engineering projects that were significantly different. The projects differed in innovativeness – Project A required the development of innovative technology and components and their application in largely unknown environments, while the Project B utilized well established best practices to maximize efficiency in solving a familiar problem in a new location. In total, 19 engineers volunteered to participate in phenomenological interviews lasting approximately 50 minutes each – 12 from Project A and 7 from Project B. The interview questions were designed to elicit insight about knowledge domains through questions such as “What were you responsible for designing and creating?” and “How do you know the work you complete is correct?” All participants were offered compensation but only participants from Project B accepted.

Once the practicing engineer interviews were completed, engineering students were recruited. Recruitment of engineering students occurred at both a large public university (> 20,000 students) and a technical college (< 5,000 students) by contacting senior design course instructors that corresponded to the disciplines represented in the real-world engineering projects. Senior design course instructors either emailed the recruitment solicitation directly to their class or posted it on their classroom management software (ex. Canvas). Interested students emailed the researcher directly and coordinated a time for a 50-minute interview. A total of 13 students were recruited from the technical college spanning five engineering disciplines: Civil, Mechanical, Software, Embedded Systems, and Renewable Energy. From the large university, 29 students participated spanning eight disciplines: Civil, Mechanical, Computer, Biological, Nuclear, Environmental, Chemical, and Electrical.

Student interviews were based on clinical interviews designed to elicit student reasoning with the help of the interviewer. The interviews utilized a simplified project description of Project A and Project B. Students only responded to questions about one of the projects, which was dependent upon their discipline. During the interviews, students first read the project description and selected a role they felt most comfortable and prepared to talk about. For example, a civil engineering student read Project B and selected the area surrounding the building (parking, run-off, etc) before being asked what they think they would be responsible for designing or creating. The students were asked to focus on a singular role when responding to questions in order to provide focus to the interview and to gain an understanding of how students categorized their knowledge relative to a specific project role.

All of the interviews were recorded and transcribed before data analysis occurred. Data analysis began with a read-thru of all of the raw text with a broad research question in mind: “how does the interviewee divide their knowledge into categories?” (Auerbach and Silverstein 2003). In pursuit of this question, the analysis focused on discussions about responsibilities, design decisions, and interactions between engineers working on the same project. Next, we coded the data for repeating ideas which resulted in a theme about how students and engineers bound their knowledge. Within this theme, we analysed student responses to one question: “Are there aspects that you think you have to rely on other people to assist you with?” For comparison purposes, we analysed practicing engineer responses to a similar question “Are there certain areas that you’ve had to rely on others to assist you with?” This question was purposefully left open-ended to allow students and practicing engineers to answer it as they saw fit. Next, we created finer grain codes that identified the ways students and practicing engineers bound their knowledge which are presented in the following section. Comparing students to engineers in this manner provides insight about where students are currently in their organization of knowledge compared to how engineers actually practice. Comparing the two therefore is important in understanding in what ways engineering education can be improved.

Results and Discussion

Our findings show that students mostly referred to the interfaces between knowledge domains as fixed and well-defined compared to engineers who saw these interfaces as dynamic and ill-defined. In other words, students treated these interfaces as consistent, predictable and easily perceived. Students viewed their interactions with the interfaces in terms of receiving facts and figures, while the practicing engineers treated the interfaces as a fuzzy grey area that required them to interpret and negotiate.

For example, many students said something similar to this quote:

As long as I had all the information [I could do my design]. [Student]

The information the student was referencing is the information necessary to complete their design and signifies that the student sees a clear divide at the interface between what they know and what others know, and a fairly simple process of communicating the necessary knowledge across the interface. This is in contrast to how the practicing engineers spoke about the grey area that exists at interfaces which is seen in the following example.

The design manager has kind of the ability to give input over the different disciplines and make decisions when we may wanna to go one way or the other. [Practicing Engineer]

Like many of the engineers, this participant's response focused on the circumstances where two disciplines have a conflicting idea about a design component. This response takes for granted that there are multiple solutions from different perspectives, and moves on from that assumption to discuss details of how to manage the interface between project roles and disciplines.

We build on the previous idea of students seeing interfaces as a simple communication process by showing that students often view communication at interfaces as one-directional.

Yeah, I'd definitely be relying on other people for information like air space and how much liquid I can bring on the actual trip, how much weight I can take up, and all that stuff. [Student]

Here, the student speaks about receiving design parameters – like weight – from "other people" showing that the student sees a division between what they know and what others know. This quote makes it clear that the student is treating this interdisciplinary information as design parameters and constraints, without acknowledging their own role in providing information or negotiating constraints across those boundaries. While this reflects typical practices in an academic setting, the student fails to recognize that there is room for negotiating these parameters with a well-formed and supported argument. Unlike the students who speak about receiving knowledge in a one-directional path, the practicing engineers' discussions at the interfaces occur on a bi-directional path or in a circular motion.

And I have relied on their input on whether or not the wall thicknesses are appropriate. Especially whether or not it is manufacturable, is it something they can actually build reasonably. And particularly strength and what kind of inserts will work for the threaded screws and all that sort of stuff. I have been able to go back and forth with them on some of that. [Engineer]

The mechanical engineer in this example was trying to determine if the designed polycarbonate manifold that is thermally fused together could be produced and how it could integrate with other components of the design. The key words in this quote are "input" and "go back and forth" indicating that the engineer sees knowledge at the interface as negotiable. Additionally, the phrase "is it something they can actually build reasonably" shows awareness by the engineer that while his design might fit the given parameters, it may not be manufacturable revealing that a grey area exists at interfaces in engineering. This quote is a prime example of how engineers do not see a clear divide in knowledge but instead negotiate and re-synthesize information as design progresses.

In the next examples we show how students and practicing engineers refer to interfaces relative to the process of engineering design.

Like, gathering information there's gonna be a lot of outside communication and then the design work I think happens like more within me and then within my department.[Student]

The student is focused on gathering information through communication with others on the project and says "…the design work I think happens like more within me…" suggesting that design occurs in solitude once parameters are defined by an authority. Again, this exemplifies the idea that students treat interfaces as unambiguous and straightforward. On the other hand, practicing engineers see these interfaces as ambiguous which can be seen in the following example about one discipline asking another for an adjustment.

…they may come to me and ask for an adjustment and then I've got to coordinate that with everybody else, structural and everybody to make sure that it's not going to be a problem. [Engineer]

Here, we see how one engineer asked for an adjustment which caused a ripple effect in the design by other engineers. This shows how design parameters are often fluid and changing and open for negotiation.

Conclusion and Next Steps

In sum, a majority of students defined interfaces (and thus knowledge boundaries) as fixed and well-defined unlike the practicing engineers who spoke about these interfaces as dynamic and ill-defined. This supports findings from similar studies that show students struggle bridging the divide between what they learn in class and the "real" world (Elby 2001, Hammer and Elby 2003, Lising and Elby 2005). This finding adds to the literature by better understanding specific locations where students struggle to bridge the divide between the academic setting and the workplace.

Understanding how students categorize knowledge at interfaces has provided insight about how students' categorizations differ from practicing engineers. This echoes previous research that suggests that students' development of knowledge is likely to be bound in an academic or classroom context (Brown et al. 1989). The research presented here adds to the body of existing literature by suggesting a shift from understanding personal epistemology to understanding epistemic practices. Additionally, our findings suggest the need to incorporate epistemic practices found in engineering practice early on in the educational experience so that students are prepared to enter engineering practice. For example, by providing students more opportunities to work on open-ended and ill-structured problems that have multiple "correct" solutions.

Next steps include a more in-depth analysis comparing the students with practicing engineers. By doing so, we hope to uncover additional dimensions of epistemic practices in which students and engineers differ. Additionally, we plan on proposing modifications to teaching practices that could expose students to the epistemic practices commonly found in engineering practice.

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Mapping the Integrated Research Landscape on Gender and Teamwork in Higher Education: 2000-2016

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CONTEXT

Employers and education researchers alike increasingly advocate teamwork as a means of developing skills that engineering graduates need, and accreditation bodies consider the ability to both lead and function on teams as an important outcome for engineering graduates. At the same time, we know that teamwork can be a site for the manifestation of gender biases. The literature is full of conflicting findings on how teamwork can promote and/or hinder diversity in education, and those conflicting findings need to be made sense of so that best practices can be implemented. To that end, we are conducting an integrated literature review of higher education research on gender and teamwork. This paper builds on and advances other meso-level analyses of gender in engineering education research that have been published over the past decade.

PURPOSE

The purpose of this paper is to analyse the higher education research landscape related to gender and teamwork with the aim of identifying how it should inform engineering educators' practices, and how it should inform future engineering education research.

APPROACH

This paper is a meso-level analyses of higher education journal articles published between 2000 and 2016. An international dataset of 54 articles about gender and teamwork, primarily from engineering and business fields, was analysed. As a first step in mapping that body of literature, this paper presents findings on geographic and disciplinary origins, methods utilized, topics studied, and gaps that future research should address.

RESULTS

The leading topics investigated were: effects of team composition; student perceptions and/or experiences; self and/or peer evaluation; and learning styles. Across the board, findings were mixed, such that it is hard to draw conclusions related to any facet of teamwork based on this integrated, multidisciplinary dataset. Similar to prior meso-level analyses in engineering education, we found that almost all articles utilized quantitative methods and very few engaged gender theories.

CONCLUSIONS

Several limitations of the research landscape are important to highlight: 1) dominant research designs and questions may not be the best for capturing the experiences of minority groups or understanding gender in teamwork; 2) important findings from books and conference papers are not yet reflected in the articles; and 3) use of ill-supported concepts, such as learning styles and Myers-Briggs, instead of gender theories is problematic, and future research should more deeply engage gender theories. If possible, a systematic metaanalysis of this dataset would be useful, and, given the mixed results present in the dataset, researchers should be cautious about claiming teamwork is inherently good for diversity.

KEYWORDS

Gender, teamwork, PBL

Mapping the Integrated Research Landscape on Gender and Teamwork in Higher Education: 2000-2016

Introduction

Teamwork is increasingly seen as an important component of engineering education programs (Borrego, Karlin, McNair, & Beddoes, 2013; Male, Bush, & Chapman, 2010, 2011; Paretti, Cross, & Matusovich, 2014; Purzer, 2011). Employers and education researchers alike advocate teamwork as a means of developing skills that engineering graduates need (Purzer, 2011), and Engineers Australia considers the ability to lead and function on teams as an important outcome for engineering graduates (Engineers Australia, 2016). However, "despite the clear emphasis on teamwork in engineering and the increasing use of student team projects, our understanding of how best to cultivate and assess these learning outcomes in engineering students is sorely underdeveloped (McGourty et al., 2002; Shuman, Besterfield-Sacre, & McGourty, 2005)" (Borrego, Karlin, McNair, Beddoes, 2013, p. 473).

One aspect in which this is particularly true is understanding how to best cultivate and assess the inclusivity of teamwork, and understanding the ways in which teamwork does and does not support diversity in engineering. In order to advance discussions on those topics and synthesize the dispersed body of research on gender and teamwork in higher education, we are conducting a meso-level literature review of articles published between 2000 and 2016. This paper is a first step in mapping that body of literature. Where does it comes from? What methods are being used to answer what questions? What kinds of questions and topics are being explored and which are not? What theories are being engaged? What gaps can be identified? By providing an integrated analysis of the higher education research landscape, this paper joins other meso-level analyses of the gender and engineering education research and responds to calls for more such analyses (Beddoes, Borrego, & Jesiek, 2009; Jesiek & Beddoes, 2013; Pawley, Schimpf, & Nelson, 2016.) Meso-level analyses are midway between purely quantitative and purely qualitative publication analyses, combining aspects of both.

Methods

EBSCO host, which includes multiple databases such as Academic Search Premier, Educational Research Complete and ERIC, was searched for articles about gender and teamwork. Most engineering education journals and higher education journals were all found within EBSCO host, though often the most recent one to one and a half years of articles were unavailable. With that in mind, *European Journal of Engineering Education* (EJEE), *Journal of Engineering Education* (JEE), *Journal of Higher Education*, *Studies in Higher Education*, and *Research in Higher Education* were individually searched for any missing articles from recent years. Originally, only publications that referred to engineering were included, but due to the limited amount of research found in engineering, the scope was expanded to STEM contexts, and subsequently even further to all post-secondary contexts. Expanding the search to all post-secondary contexts was done in order to provide readers with a comprehensive review of relevant issues. An extensive list of search words and word combinations was utilized, including the terms *gender, female, women, education, STEM, team work, group work,* and *sex*. The combinations of terms are specified in Table 1 and Table 2. In order to yield a manageable dataset of the most relevant journal articles, the scope was limited to articles published between 2000 and 2016 and to research articles directly related to higher education contexts. Limiting the search to traditional higher education contexts excluded articles related to health care professionals, primary education (K-12) contexts, and online courses (due to their different considerations). Our search also excluded certain types of publications that were not strictly research articles (e.g., panel summaries, teacher reflections, and descriptions of implementation activities).

Table 1. EBSCO host search

Terms	Combined with
Education, gender and	• Team/s • Teamwork/team work • Groupwork/group work • PBL
Education, women and	
Education, female and	
Education, gender, STEM and	
Education, women, STEM and	
Education, female, STEM and	

Table 2. Individual journal searches

Terms	Combined with
Team/teamwork/team work and	• Gender • Sex • Women
Group/Groupwork/group work and	
PBL and	

After the exclusion criteria were applied, the dataset yielded 54 articles for analysis. Fifty-one of those are accounted for in the Findings below. The remaining three will be included in our systematic literature review, but are of a different sort than the rest of the dataset, e.g. a metaanalysis or report. As with any dataset, there are limitations to note. In order to scope a manageable dataset, we were not able to include non-English language articles, books, or conference papers.

Findings and Discussion

Our first research question concerned the origins of the research, both in the geographic and disciplinary sense. Table 3 presents the geographic origins of the dataset, showing that the vast majority came from the United States, with Europe and Australia contributing the second and third highest numbers, respectively. There was only one international collaboration present in the dataset; it was between Qatar and the United States.

Table 3. Geographic origins

Country	Number
United States	24
Australia	5
United Kingdom	4
Denmark	2
The Netherlands	2
Turkey	2
Qatar and United States	1
Belgium, Canada, China, France, India, Malaysia, Norway, South Africa, South Korea, Spain, United Arab Emirates	1 each

Table 4 presents the disciplinary origins of the dataset. Discipline was assigned based on the setting in which the study was conducted, not necessarily the researchers' fields. *Business* includes business, economics, organizational behaviour and management articles. *Sciences* includes physical and health sciences. *Multiple disciplines* included articles with more than four disciplines represented, usually with engineering and business among them.

Table 4. Disciplinary origins

Discipline	Number
Engineering	17
Business	11
Sciences	5
Multiple disciplines	5
Computer science and information systems	3
Science and Engineering	2
Education	2
Psychology	2
Education and Marketing	1
Hospitality, Geography, Music	1 each

As summarized in Table 5, the vast majority (80%) of the dataset was quantitative studies, either purely quantitative data or quantification of qualitative data. Even in the mixed methods studies, the quantitative data was prioritized, with qualitative data being secondary. This finding further confirms the dominance of quantitative research documented in other studies of gender research in engineering education (Beddoes, 2012; Pawley, Schimpf & Nelson, 2016). The quantitative data was primarily from student surveys. Self and peer evaluations, or, to a lesser extent, student surveys combined with course marks/grades. Over the course of 16 years, only 4 qualitative articles were found. That is striking and important to note because quantitative methods, and student surveys in particular, may not be the ways to identify and explore problems. Indeed, recent research shows that engineering professors recognize that peer evaluations are not likely to capture instances of gender bias or discrimination if they occur (Beddoes & Panther, 2017).

Table 5. Methods utilized

Methods	Number
Quantitative	38
Mixed quantitative and qualitative	6
Qualitative	4
Quantification of qualitative data	3

The leading topics being investigated in the dataset were students' perceptions, experiences, and attitudes related to teamwork; the effects of different team compositions; self and/or peer evaluations, and learning styles. Other topics included evaluation of women's contributions and expertise and comparison of lecture to teamwork. Across the board, findings on these topics were mixed, and often contradictory, such that it is hard to draw conclusions related to any facet of teamwork based on this integrated, multidisciplinary dataset. The research in the dataset does not build on prior work or present a trajectory of comprehensive development in any way. This lack of systematic development limits the ability to draw conclusions or make recommendations for best practices because there is not sufficient research on any one topic. For example, the "team composition" category included studies that examined the effects of team composition on: motivation, team quality, cognitive complexity, class performance, final report, interactions, satisfaction, diversity management skills, self-efficacy, learning, idea variety, and innovation, to name just a few. Thus, there are a small number of studies on a larger number of topics, rather than systematic development of knowledge related to a core set of questions.

In addition to the systematic lack of development, the lack of engagement with gender studies or theories was striking. Although there were several notable exceptions, instead of engagement with gender studies research, it was more common to see authors utilizing ill-supported concepts, such as learning styles and Myers-Briggs, to frame their studies.

Conclusion and Next Steps

This meso-level analysis identified several limitations of the higher education research landscape related to gender and teamwork. First, the dominant research designs and approaches may not be the best for capturing the experiences of minority groups or understanding gender in teamwork. Similar to prior meso-level analyses in engineering education, we found that almost all articles utilized quantitative methods. Second, important findings on gender biases in teamwork from books and conference papers are not being built upon. While this may be understandable in the case of some conference papers which have come out in recent years (see Meiksins et al., 2016 and 2017), it is a problem in the case of books such as *On The Outskirts of Engineering*, which was published in 2007 (Tonso, 2007). Third, the use of ill-supported concepts, such as learning styles and Myers-Briggs, instead of gender theories is problematic, and future research should more deeply engage with gender theories. Fourth, the lack of consensus in the dataset, combined with the lack of systematic development, makes it difficult to draw conclusions or make recommendations. What can be recommended is that researchers should stop making unqualified claims that teamwork necessarily or automatically supports diversity or helps women. Many studies in the dataset (as well as others not in the dataset) do not support such claims. Those interested in advocating teamwork should equally account for the studies that do not support their aims. Otherwise, we risk implementing pedagogical practices that perpetuate the very problem they were intended to solve. By including our dataset as an appendix at the end of this paper, we hope to make that more feasible for others.

In sum, much more research is needed, and that research will be most useful if a research agenda for gender and teamwork in higher education was developed and followed. If the community developed a list of questions and then set about to systematically investigate them, instead of one or two articles about 35 different topics, we could begin to systematically develop evidence across contexts that would eventually allow a sufficient body of knowledge upon which to make claims and draw recommendations. With or without such an agenda, future research should include greater use of qualitative methods, feminist methodologies, and gender theories.

For our part, our next steps, we will be adding 2017 articles to the dataset, analysing in greater depth the theory and findings in the dataset, and writing a systematic literature review.

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Appendix: Dataset

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An initial step towards developing techno-entrepreneurs in the engineering curriculum

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SESSION

C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

CONTEXT

Innovation and creativity are essential and related to entrepreneurial learning, skills, knowledge and mindset. Previous research specified requirements for engineering educational programs to boost students' creative skills in engineering. In order to enhance creative thinking among engineering students, our teaching team has developed an interdisciplinary subject integrating entrepreneurship components into a traditional operational management perspective. Our teaching team endeavoured to build capabilities that allow future engineer graduates to engage in a creative process to solve a problem or to design and make a new artefact and become techno-entrepreneurs. Our works analysed whether a major assessment within a subject in third year engineering curricula – a team project to develop a business plan based on a new idea – help students to implement their learning into tangible outcomes and develop their creative skills.

PURPOSE

The main research question in this paper is whether students utilize or implement the lecture content in their group projects to learn effectively and enhance their learning.

APPROACH

Researchers in this paper analysed students' projects, which were submitted as group assignments during three years between 2014 and 2016 in regards to how students applied the lecture content and tutorial activities in their projects. Focusing on creativity and innovation as the main elements of selecting a new idea for the project, we evaluated whether the teaching and learning process helped students to learn and apply concepts of creativity and innovation in a practical project. In addition, we were looking to classify types of ideas and areas of businesses that engineering students have been interested in.

RESULTS

The findings showed that majority of engineering students were focusing on new technologies to introduce new products and develop new services. On the other hand, although the concepts of creativity and innovation are necessary for their projects, students mainly followed up the current trends in technologies that pioneered by large corporations in high tech industries. In these circumstances, it seems students followed the type of innovation known as "incremental innovation" or steady improvements based on sustained technologies.

CONCLUSIONS

Students paid attention to the concept of creativity and incremental innovations in their projects as part of the lecture content and learning objectives, but often they did not try radical innovations or fundamental rethink based on disruptive technologies. This evidence encouraged our teaching team to modify the requirements of projects, give more values and marks regarding radical innovation in assessment rubrics and at the same time, take more emphases in lectures and tutorials to encourage students to try radical innovations.

KEYWORDS Creativity, entrepreneurial mindset, innovation, engineering students

Introduction

In the article written by Jack McGourty (2009) for Journal of Engineering Education, he reviewed a recent study of engaging peer-engineering schools in entrepreneurship educational programs for their engineering students. McGourty (2009) raised a question why there is a growing educational focus on entrepreneurship in higher education. Then, he responded that the world's attention concentrated on the global economic crises. He continued that while Fortune 500 companies are making public announcements in regards to job losses on a daily basis, entrepreneurs are generating millions of new jobs. For instance, in 2007, small and medium firms managed just below one million new employments. There is another evidence, which Robert Waters (2010) restated and referred to the analysis of the US Census data from 1976 to 2005. The results illustrated that each year, new firms created approximately two-thirds of new occupations in the US and the technology sector established significant portions of these jobs. In regards to engineering education, McGourty (2009) believed that while business schools host the majority of entrepreneurship programs, engineering schools are recognising that entrepreneurship is a vital area of study for engineers and applied scientists. Waters (2010) viewed this matter too and mentioned that although there are an estimated 600 engineering schools in the US, only around 23 engineering programs propose formal technological entrepreneurship education. One of interesting observations by Waters (2010) in his article is that while he reviewed the entrepreneurship programs in different universities he also focused on whether there is entrepreneurship education in engineering management programs. His findings showed that entrepreneurship education has not penetrated into more engineering management programs. There are some reasons such as: the dominance of the business schools in the field of entrepreneurship or with declining university budget, some executive deans may hesitate to fund new activities or courses that they do not consider "real" engineering.

Our work outlines the learning process within a particular subject in our institute's third year engineering curricula. The teaching staff in this subject teaches concepts of operational management; however, in order to address Engineers Australia's suggestions, we teach some business aspects such as: Finance and Accounting, some Legal concepts that engineers should know (e.g. elements of Contract Laws, aspects regarding Intellectual Property – IP) and also teach basic entrepreneurship skills to engineering students. Students have to form a group with their peers in tutorial class and work on an entrepreneurial business plan as part of their research project.

Literature Review

In the era of rising market competiveness and business forces, there is an essential need for engineers with entrepreneurial knowledge and skills. Among these skills, we can focus on abilities that have links to creativity and innovation. Although many scholars defined creativity and innovation, we use definition by Byers, Dorf and Nelson (2015, pg. 164) as "Creativity is ability to use the imagination to develop new ideas, new things or new solutions." They also defined Innovation as invention that has produced economic value in the marketplace. In regards to engineering education, Rodrigues and her co-authors (2015) mentioned that the traditional engineering curriculum often does not offer students an entrepreneurial education. Tom Byers and his colleagues (2013) believed that ongoing innovation is required to address pressing problems and helped firms to survive in high global competitive environments and engineering is the foundation of much of that innovation. Rodrigues and her peer researchers (2015) pointed out those students from any discipline or program with entrepreneurial training can contribute valuable skills to the workplace. In the same context, another group of professionals led by Byers (2013) focused on engineers and said that in additional to their technical and analytical expertise, engineers need to be creative and have ability to recognise and capture opportunities. All of these skills as well as being able to cooperate effectively as leaders, in teams, and with their peers can and should be taught to engineers as part of their formal education. In other words, some researchers such as Rodrigues and her team (2015) figured out that engineering schools and institutes should teach engineers how to manage interdisciplinary teams, think critically, understand business basics, communicate effectively, and solve open-ended problems. Referring to the above comments from different researchers and professionals, engineering educators should understand that they have responsibilities to enhance the above skills in their engineering students and enable them to be more innovative and entrepreneurial. To support the above points, Remeikiene and her research partners (2013) explained the results of a study conducting among students in two different programs, Economics and Mechanical engineering, at Kaunas University of Technology in Lithuania. They concluded that programs in higher education institutions should develop entrepreneurial capacities and especially those programs designed for the students with technical specialization should have subjects enabling students to practice entrepreneurial knowledge and skills. Nelson and Byers (cited in Byers et al. 2013) believed that for engineers, who completed formal entrepreneurship programs; the above skills and knowledge give them solid experience in market analysis, product design and development, prototyping, and understanding technology trends.

One of the skills that almost all entrepreneurship programs focus on is enhancing creative thinking and being innovative. According to Daly, Mosyjowski and Seifert (2014) a university course can improve students' creative skills by supporting course content, training materials and components, assignments and tests. In another words by developing the environment towards creativity-focused learning goal, universities can enhance students' creative skills. They reviewed many research outcomes and restated that students can develop and foster their creative skills by focusing on training on cognitive skills, which are necessary active components in enhancements on students' creativity skills. Researchers such as Daly, Mosyjowski and Seifert (2014) described creativity as a type of novel thinking, where in the field of engineering, this emphasizes on the need to meet functional requirements in a novel way. Concerning the definition of cognitive processes in creativity, Fink, Ward and Smith (cited in Daly et al. 2014) pointed out that thinking patterns including problem finding, information gathering, idea generation, and idea evaluation are main parts of cognitive processes, which guide students to creative tasks.

Reviewing literature illustrated that a common instructional approach in engineering education in relation to enhancing creativity skills is open-ended projects, where instructors will not define the target product in order to allow students to search for creative opportunities. Most of times students work on teams in their projects to generate solutions and instructors also allow students to choose their own project topics. From instructors' points of view, they often offer students different tools to guide students to either consider important aspects of a problem or help them to generate ideas and new designed products or services.

The specific research question in this paper is that:

Do students utilize or implement the lecture content in their group projects to learn effectively and enhance their learning?

In the next stage of this paper, we summarise the main contents of a particular subject in our institute. This also provides information in regards to how our teaching team through a wide range of lectures and tutorial activities teach basic entrepreneurship skills and combine the concept of operational management with developing a new business plan for a start-up firm.

Particular subject unit and its contents

This subject is part of our institute's third year engineering curricula and several engineering programs such as Mechanical, Civil, Product Design, and Robotics and Mechatronics engineering programs offer this subject in their curricula. Figure 1 shows the main concepts that our teaching team addresses during 12 weeks lectures.

The contents of this subject are including of operational management focusing on technical aspects used by managers of firms and some basic knowledge of business fields that engineers should learn.

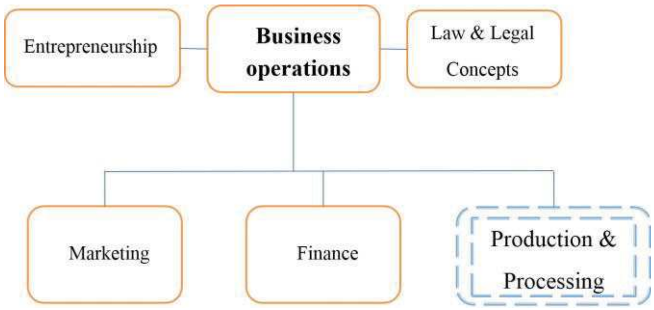


Figure 1: The main concepts which be taught during 12 weeks lectures

This subject is part of engineering curriculum, and therefore, our teaching team focuses on different aspects of “Production and Processing” during 7 weeks of semester. In Figure 2, more details are available regarding “Production and Processing”, and we link different aspects from “Operation Strategy” to “Operation Management”.

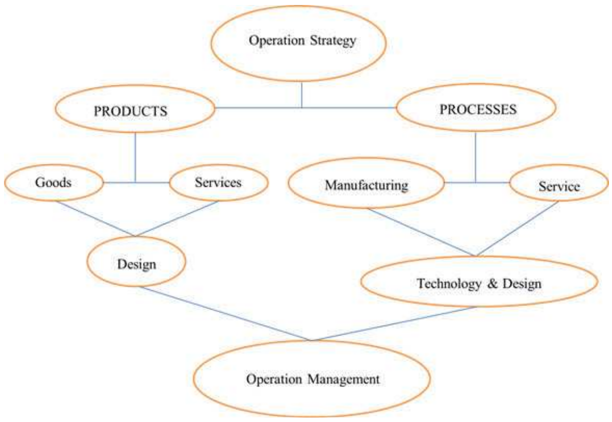


Figure 2: The pathway from “Operation Strategy” and its components to “Operation Management” within the section “Production and Processing

Figure 3 shows that the teaching team looks at other related aspects to operation management. For those new operational activities, the teaching team also looks at the concept of project management.

In addition to 12 weeks considering 3 hours lecture per week, students have to attend 2 hours tutorial classes during 9 weeks. There is no tutorial in weeks 1, 5, and 8 of semester.

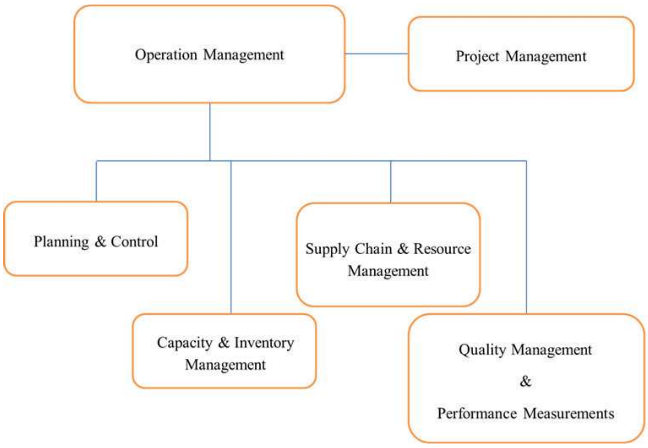


Figure 3: The components related to the concept of operation management, which be taught during semester period

Part of student's assessments, there is a research project that students should work as a team and based on a new idea. Students need to complete their business plan for establishing a new venture by the end of week 10 of the semester and present their plan either in week 11 or week 12. The value of research project is 34% of total final mark for students and there are four stages that teaching team evaluates students' research projects. In week 5, instructors evaluate stage one followed by week 8 as stage two. The last two stages are final report in week 10 and presentation in weeks either 11 or 12.

In their research projects, which we consider as a business plan for establishing new venture, students need to introduce a new idea either as a product or as a service or even combined product and service. They need to provide market and customer analysis, define target market, address technical process requirements including design process and requirements, quality control process and requirements and inventory management and supply chain management.

Students must address some legal and financial aspects in their business plan and there are guest lecturers who teach these concepts during semester. Meanwhile, instructors also provide some guidelines to students and provide feedback to students during semester in different stages.

Methodology

This paper reflects on teaching activities in one particular subject in our institute's engineering curricula. In this paper, researchers paid attention to three aspects of lecture content, which are creativity, innovation and entrepreneurship. The focus was on whether students try to think creatively and develop a new idea to solve a problem, develop a new service or product and establish a new venture. For this purpose, in each semester, the lecturer spend one hour of lecture in week one on the concept of creativity, innovation and entrepreneurship and distribute a document as a guideline for encouraging students to think about new problems, trends, ideas and compare products/services and technologies, new and old. Then, following up of that particular lecture, teaching team in week two during two hours tutorial encourages students within a team to come up with a new idea to establish a business. Teaching team uses some slides and notes to help students in their process of developing new ideas such as Figure 4.

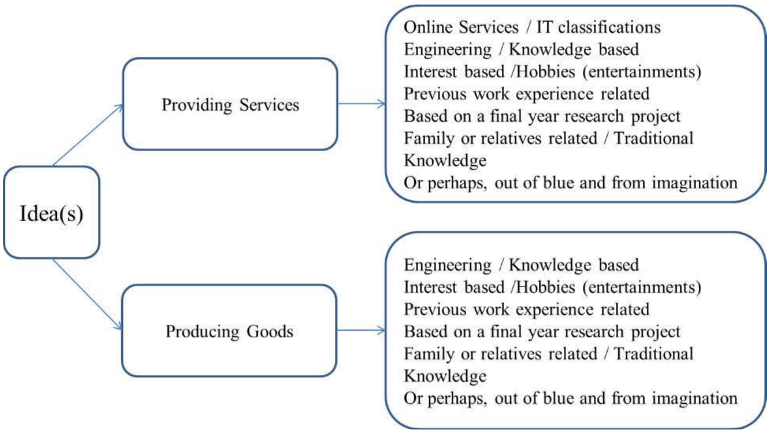


Figure 4 – Concept tree approach to help students find an idea

Focusing on creativity and innovation as the main elements of selecting a new idea for the projects/business plans, we evaluated whether the teaching and learning process helped students to learn and apply concepts of creativity and innovation in a practical manner. We analysed students' projects submitted as group assignments during three years from 2014 to 2016. We obtained data from final reports of students' projects (as group projects) and we collected data via Blackboard (LMS) system as students needed to upload their projects into Blackboard. We reviewed the contents of reports and based on classification showed in Figure 4, we identified whether students were looking to create new services or make a new product. Then, by studying students' reports in details, we identified how students decided to work on new ideas and develop a business plan based on the ideas. We have undertaken further work to check the reliability of findings.

It is worthy to consider that students can choose either a product or a service. According to a guideline provided to students during tutorials, students can also choose ideas based on their previous work experience as a full time or part time employee, their hobbies and interests, family and cultural background and even based on just their imagination and out of blue. The Figure 4 shows student can choose the topic using concept tree approach.

In addition to the above, we were looking to classify types of ideas and areas of businesses that engineering students have been interested in.

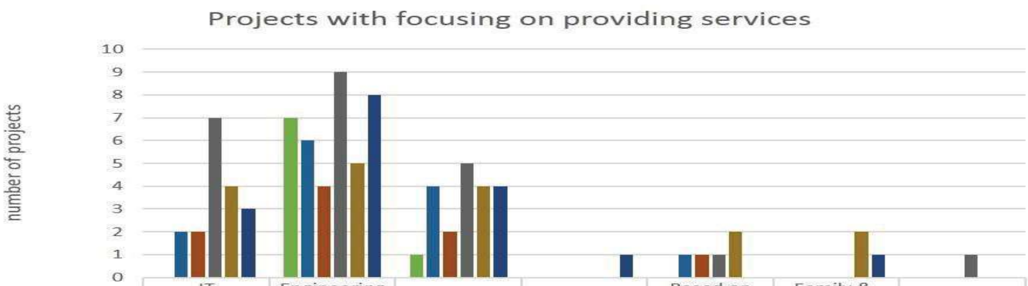
Findings and discussion

During one hour lecture in week one every semester the lecturer of this particular subject explains two different types of innovation. One is "incremental innovations", which are mainly about steady improvements and based on sustained technologies, e.g. improving smart phones. Byers, Dorf and Nelson (2015) mentioned that people could categorize incremental innovations as quicker, improved, and/or low-priced version of existing products. Another one is "radical innovations", which are mainly about fundamental rethink and based on disruptive technologies, e.g. developing iPod by Apple Corporation or as Byers, Dorf and Nelson (2015) mentioned that 3D printing is an example of radical innovation because radical innovation could transform the relationship between customers and suppliers, restructure the markets by creating new product categories. We believe that in real world practices, only few very smart and creative minded people pursue radical innovation and we should call most of other innovations as incremental innovations. Therefore, in order to classify different ideas, we proposed in our context that while students were using the contents of their final year research projects as the basis of their new ideas, they might be able to rethink of the usage of technologies radically. This approach will allow authors of this paper to classify those projects as attempt to have "radical innovation" - because those students' projects would not be ready for the real world. Without any doubt, we have strong opinions that behind those high tech devices that changed the lives of people around the world, and can call them as "radical innovation", there were technological experts that created new products and services. On the other hand, if students only used their engineering knowledge and developed new ideas, we classified students' ideas as "incremental innovation".

From 2014 to 2016, students within a group of three to five have submitted 288 business plans as part of students' projects in this particular subject. We looked at what type of ideas students used as a new approach to providing a service or producing products. The teaching team asked students to come with new ideas and being creative/innovative and write a business plan based on new ideas.

After reviewing the ideas behind groups' projects, in regards to providing services, we found that majority of students in groups used engineering and knowledge-based contents for basis of new ideas for their research projects (business plans) in each semester during a period of 2014 to 2016. We considered these types of innovation as "incremental innovations" (39 out of 87 – 44.8%). In regards to providing services, we considered only very few projects as "radical innovations" (5 out of 87 – 5.7%) due to use final year research project as a basis of their ideas. The Figure 5 shows distributions of projects based on source of ideas, which focus on providing services.

In regards to producing goods and making tangible products, engineering students showed their passion to focus on manufacturing and technical knowledge for their ideas for business plans. In fact, the total number of business plans focusing on producing goods is more than double of those focusing on providing services (201 research projects/business plans compared to 87).



	IT Classifications/Online services	Engineering & Knowledge based	Interest & Hobbies	Previous work experience	Based on Final Year Research Project	Family & Traditional/ Cultural Knowledge	From Imagination
Sem 1 2014	0	7	1	0	0	0	0
Sem 2 2014	2	6	4	0	1	0	0
Sem 1 2015	2	4	2	0	1	0	0
Sem 2 2015	7	9	5	0	1	0	1
Sem 1 2016	4	5	4	0	2	2	0
Sem 2 2016	3	8	4	1	0	1	0

classifications of sources of ideas

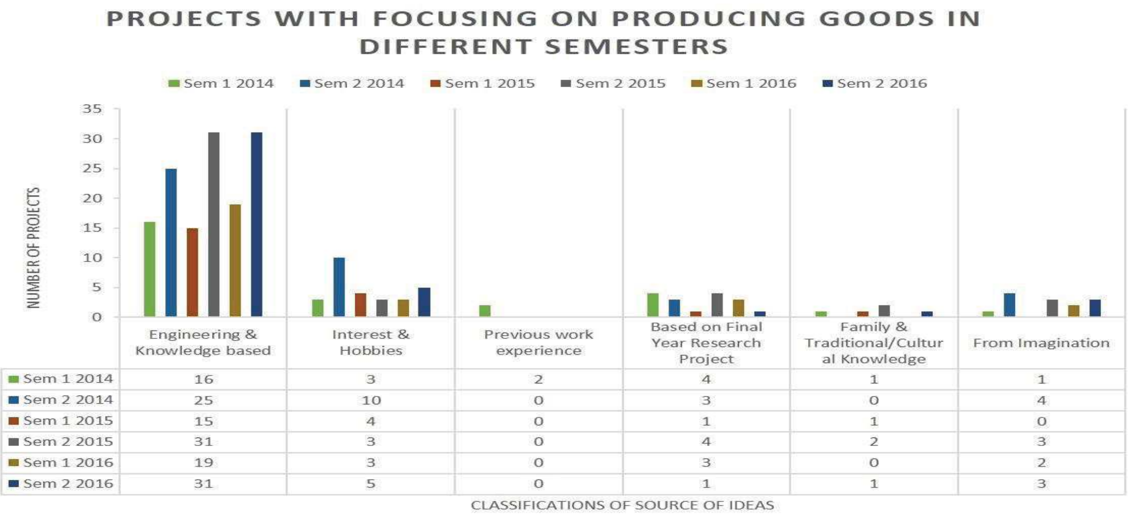
Sem 1 2014 · Sem 2 2014 · Sem 1 2015 · Sem 2 2015 · Sem 1 2016 · Sem 2 2016

Figure 5 – Classification of sources of ideas in projects focusing on services

It also showed that engineering students used more their final year research projects as sources of ideas for making products than providing services (16 ideas compared to five ideas respectively). While 137 groups of students (68.2%) looked at their engineering knowledge for sources of new ideas for producing goods and tangible products and we considered their approaches as "incremental innovations", only 8% of students groups (16 research projects/business plans) tried to approach as "radical innovations" based on their final year research projects. The Figure 6 illustrates the types of sources for new ideas to develop tangible products and producing goods.

We understand that other types of sources might provide opportunities for a new business plan and new venture start up based on incremental innovations or even radical innovations;

however, in this paper, we focus on the areas that students used their engineering knowledge, either general engineering knowledge or based on final year research projects. We expect and assume that students would like to pursue their future career in their field of knowledge.



	Engineering & Knowledge based	Interest & Hobbies	Previous work experience	Based on Final Year Research Project	Family & Traditional/Cultural Knowledge	From Imagination
Sem 1 2014	16	3	2	4	1	1
Sem 2 2014	25	10	0	3	0	4
Sem 1 2015	15	4	0	1	1	0
Sem 2 2015	31	3	0	4	2	3
Sem 1 2016	19	3	0	3	0	2
Sem 2 2016	31	5	0	1	1	3

Figure 6 – Classification of sources of ideas in projects focusing on products

It is also very difficult to say that all ideas were 100% new. We understood that students tried hard to convince teaching team that their ideas were to some extent new. For example, students might say that they were targeting new type of customers, or new geographical locations and providing services or products to customers that previously not served by other companies. This paper has limitations to address all questions scholars may have while analysing all projects and we have plans to overcome difficulties in this matter. This paper is a starting point to better understanding where students are looking for new ideas. We know that we have to work hard to provide a holistic picture in this area.

Meanwhile, we are able to present other findings such as special trends by students to look at some ideas used or developed by very big organisations. Students tried to form a group with other students enrolled in the same program, e.g. in some groups all students studied Civil and Construction engineering program or Mechanical and Product Design Engineering. We could recognise some trends in new housing structure, pre-cast concrete, modular housing with particular approach based on their Civil or Construction programs. We recognised several approaches to use drones by wide range of students. Prototype manufacturing, 3D printing, using new and complex materials for making products, using iPhone and developing apps, developing medical devices and making special clothes are very popular ideas among all types of engineering students.

Conclusion and recommendations

Although teaching team tried to encourage students to find new ideas and approach to their ideas as radical innovations, but students could not have enough time to come with a brilliant ideas. In addition to above points, it seems to us that students did not have enough motivation to think seriously about new ideas, and therefore, students came with similar ideas from another group either in the same tutorial or from another tutorial. It is very important for teaching team to provide feedback to students and has authority to reject an idea due to similarity with very popular trends in the current market. Having said that, we found a wide range of ideas generated by students and it is interesting that engineering students were focusing more on producing goods and tangible products than providing services only.

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Interdisciplinary Collaborative Teaching in Project-Based Learning Approach

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CONTEXT

It is common for Engineering and Technology programs to nurture interdisciplinary courses when aspirant graduates need comprehensive knowledge and skills to start working even before their graduation. These hybrid courses usually demand collaborative teaching to ensure high expertise of educators to provide for requirements of different disciplines. The Bachelor of Information Technology and the Bachelor of Electrical and Electronic Engineering are two disciplines with close bonds between hardware and software. The course design, implementation and evaluation should be reported to reflect good practice from collaborative teaching in an interdisciplinary environment.

PURPOSE

The study details the process of designing and implementing an interdisciplinary collaborative teaching in Project Based Learning (PBL) approach, and reflects on its benefits and drawbacks for both educators and students.

APPROACH

A reflection was done on the teaching practice for course alignment, preparation and delivery based on teaching journals. As for students' evaluation of the course, a post-course survey and focus group interviews were conducted. Also, an analysis of the results of students' learning outcomes (acquired course learning objectives, students' perception of the course, and their product showcase) was carried out to present the advantages and disadvantages of the course.

RESULTS

The alignment of course learning outcomes, course structure, and assessment were demonstrated. The findings showed that students succeeded in achieving the course objectives and felt positive about the course as a whole. Although, students' interviews revealed some drawbacks of the collaboration, it did not significantly impact the students' learning. Besides, the collaboration of lecturers was generally a success, but still recommendations were given for the improvement of the course delivery.

CONCLUSIONS

As regards the course design and delivery, more attention is needed in aligning and communicating to students about learning outcomes and assessment of different disciplines. As for the course benefits, authentic project work was facilitated with interdisciplinary group formation encouraging more engagement and self-learning among students.

KEYWORDS

Interdisciplinary learning, project-based learning, collaborative learning, collaborative teaching

Introduction

Project-Based Learning (PBL) enables industry authentic projects and increasing students' exposure to real-world working environment (Johns-Boast & Flint, 2009). Although PBL approach was introduced in education in early 70's (de Graaff & Kolmos, 2007), when it involves different disciplines, challenges arises in designing collaborative interdisciplinary activities, and most importantly aligning the learning outcomes and assessments for groups of students in different majors. An endeavour was conducted at RMIT University Vietnam in 2015 in PBL courses for the Bachelor of Information Technology (BIT) and the Bachelor of Electrical and Electronic Engineering (BEEE). The goals of these two courses were to provide students with knowledge and skills in working with the two closely related parts of a technological project: hardware and software, as well as learning project management. The affinity in the learning outcomes (CLOs) of two courses as stipulated by the school program and no requirement of prerequisites for these two courses allowed their integration into one class.

Background theories

To lay the foundation for understanding the PBL courses delivered to interdisciplinary class with collaborative teaching, relevant theoretical points will be reviewed below.

Interdisciplinary learning

Interdisciplinary collaborations in education are more and more common not only in closely related majors (e.g. arts and humanities or IT and engineering) but also between courses from different disciplines that hardly share any expertise like medical and legal (Morton, Taras, & Reznik, 2009), or even medicine and architecture (Mason & Pirnie, 1986)

The benefits of interdisciplinary learning are shown by a study of Abdulhalim, Sammarco, Jayasekera, and Ogbonna (2011) which describes how students from different majors benefited in sharing and learning from different perspectives, complementing each other's expertise, bridging the gap between research and practice, enhancing communication skills, and exploring knowledge and experience outside the course. Moreover Davies, Devlin, and Tight (2010) argue that higher education which "acknowledges the challenges and possibilities in interdisciplinary ways of thinking learning, knowing and being" aims at producing graduates with the ability to "recognize, reflect on and negotiate different forms of knowledge" (p. 24). Meanwhile, Borg and Borg (2001) assert that critical thinking skills are promoted when students involved in working out the differences between two disciplines to collaborate with each other. Beyond that understanding, students are believed to develop their leadership and communication skills, presentation skills and confidence, to make their learning purposeful and thus to succeed at university and later in life (Anderson, 2010).

Generally, due to the discrepancies in different disciplines, interdisciplinary courses require instructors to master different expertise; therefore, the necessity of collaborative teaching is manifested.

Collaborative teaching

Collaborative teaching and co-teaching are distinguished by Friend, Cook, Hurley-Chamberlain, and Shamberger (2010) in that the latter is under the umbrella of the former. However, these two terms are used interchangeably in many studies (Gerber & Popp, 2000; Speer & Ryan, 1998; Waters & Burcroff, 2007). In this study, collaborative teaching is understood as co-planning, co-assessing, and mixed delivery between individual lectures and joint managements of tutorials and students' presentations.

Collaborative teaching presents indisputable benefits. Besides the advantages of shared expertise, insights, new approaches, perspectives, and peer-feedback, lecturers can combine strengths and reduce weaknesses (Buckley, 1999). Also, when sharing the teaching task for a class, collaborative lecturers can be satisfied with increased students' academic achievement, improvement of teaching skills as well as collegial relationships (Walther-Thomas, 1997), and understand the position of the subject in reciprocal relation with others (Zhou, Kim, & Kerekes, 2011).

However, collaborative teaching is also loaded with different challenges such as the coordination of lecturers' schedule for co-planning, the heterogeneity of students in each class, and the provision of specialists' support, heavier administrative support, and sponsor for staff development (Walther-Thomas, 1997), the lack of time for class preparation (Goldstein, 1967), the inconsistency of emphasis on learning materials and assessment components (Carter, Barrett, & Park, 2011), and students' confusions of different lecturers' expectations (Dugan & Letterman, 2008). Therefore, endeavouring collaborative teaching can be a challenging mission for both novices and veterans.

Project-based learning

Project-based learning is the instructional approach emphasizing the learners' autonomy in a learner-centered environment where they realize ideas in projects (Krajcik, Czerniak, & Berger, 1999). In PBL courses, students' personal interests are encouraged (Wurdinger & Qureshi, 2015), so they are motivated to be greatly engaged in the learning process and thus make use of their strengths, and overcome their weaknesses in the effort to jointly create authentic products. Moreover, learner-centeredness embedded in PBL entrusts the lecturer as a facilitator, coach, advisor, and motivator besides his traditional role of a lecturer of the class (Chua, 2014; Montequín, Fernández, Balsera, & Nieto, 2013). Also, because project-based learning approach does not only teach students academic knowledge but also trains them a variety of soft skills (Chua, 2014), assessing a PBL course often requires the weighing of the following skills: individual work versus group work, cognitive skills versus metacognitive skills, knowledge versus soft skills and done as formative assessments scattered during the course and filled with the teachers' feedback for improvement. Students were assessed through presentations, observations, reflective journals, weekly reports, discussions, self-assessment, group assessment, and final product evaluation, some of which are combined in a portfolio for each student (Bell, 2010; Chu, Minasian, & Yi, 2012; Jaeger & Adair, 2015). This reflects the spirit of formative assessment, which is assessing for learning (Bell, 2010; Montequín et al., 2013; Strijbos & Sluijsmans, 2010).

Research Methodology

Action research was conducted in a class where a single instruction was given to two interdisciplinary courses namely *Software Engineering Project Management* (SEPM) for IT major and *Engineering Management* (EM) for Engineering major. The study aimed at demonstrating the implementation of interdisciplinary courses in PBL approach and reporting experiences of collaborative delivery from both lecturers' as well as students' general evaluation of the course. There were 30 IT students in the SEPM mainly at their final years while the 8 Engineering students were doing their first year. A reflection was done on the teaching practice to detail course alignment, preparation and delivery based on teaching journals of two lecturers instructing the course. As for students' evaluation of the course, a post-course survey for 38 students and 3 focus group interviews were conducted and analysed to reveal emerging themes. Also, students' learning outcomes shown in the achievement of course learning objectives, students' perception of the course, and their product showcase were analysed to expose the advantages and disadvantages of the course result.

Findings

Contributions of the study revolve around elaboration of the joint construction of the courses, the influences of the courses on students' learning, and the lessons learned from collaborative teaching.

Course Learning Outcomes and Contents

The two courses had different learning outcomes, yet the two lecturers reviewed them together and determined that they were compatible to enable collaborative delivery and common assessments as endorsed by their Program Manager. In particular the following learning outcomes can be summarized as: students' Teamwork, Collaboration, Communication skills, Human Management, Project Planning, Project Execution, Risk Management through which, the demonstration of critical analysis, problem identification, problem solving, decision making and team facilitation skills in managing Engineering projects.

Nevertheless, the lecturers had to align some of the courses' CLOs which were not equivalent. After analysis and comparison, apart from incompatible outcomes exclusively intended for each discipline, some were kept as shared outcomes as they were very beneficial for all students. For instance, "Software Development Methodologies", a part of the IT knowledge was introduced to BEEE students whereas the "Communication Barrier" (language, perception, environment and ambiguity) from EM was also kept for IT counterparts because those two topics were important to meet the CLOs.

For better achievement of those CLOs, the lecturers announced and emphasized them together with the course content in the first week and continuously reinforced these requirements after that.

Course delivery

With the course learning outcomes review and course content alignment above, the course structure was designed for the 12-week course, with 6 hours of face-to-face sessions per week as shown in Figure 1 below.

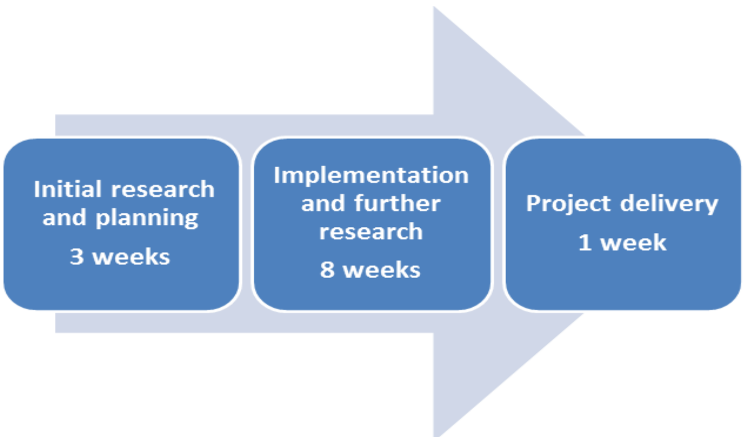

Figure 1: Course delivery structure

Each lecturer took turn to give jointly developed lectures to the combined class in a manner that encouraged students' critical thinking for working on the projects. However, both held weekly tutorials together to solve situational problems based on the project and actively managed to engage students in collaborative learning exercises. There were eight projects, namely: Gas Leakage Risk Management system, Room Temperature Management system, Smart Parking System, Refrigerator Light Management System, Online Parking system, Media Centre system, Smart Home Security and Maze Robot Solver. All of these projects required the design and implementation of complex systems including both hardware and software, which exposed the students to engineering/IT authentic situations. The final products had been designed by the lecturers and introduced to students, but the design, planning, implementation, and overall organization were figured out by each student team. However, team formation and project assignment were done by the lecturers based on the students higher education background and demonstrated strengths in their academic records in order to enhance the teams' chances for success.

In terms of group formation, mixed academic backgrounds was organized for the teams. IT students enrolling into SEPM were doing their capstone projects whereas Engineering students were conducting their first higher education projects. Each project team was constituted of 5 students with 3 or 4 third-year IT students, and 1 or 2 Engineering freshmen. The IT students, with their programming experience and skills, were carefully selected to balance the technical competency level for each group while Engineering students were expected to bring to the team their experience in working with electronic hardware. Such diversity in the background of team members was a crucial factor to which the teams must pay attention for task management where the role and responsibilities of each individual had to be specified to mitigate overlapping and conflict among the members.

Course Assessment

As these courses were the first PBL experience for both IT and Engineering students in this study, the lecturers agreed that the assessment had to be mostly formative in order to scaffold students' project management (planning, implementation and delivery) skills. The assessment scheme (see Table 1) comprised three phases; each subsequent phase built up on the previous one by having similar format and content, yet with higher complexity, providing a formative structure.

Table 1: Assessment structure

Phase	Task	Group/Individual	%	When (week)
Initial research, project proposal and planning	Report	Group	10	Week 4
	Report (individual section)	Individual	5	
	Presentation	Group	7.5	
	Presentation	Individual	7.5	
Implementation (and further research)	Report (progress update)	Group	12	Week 8
	Presentation	Individual	7.5	
	Presentation	Group	7.5	
	Peer performance evaluation	Individual	3	
Project Delivery	Report	Group	12	Week 12
	Peer performance evaluation	Individual	6	
	Presentation (Product and Showcase)	Group	22	

Impacts of the interdisciplinary PBL course on students' learning

The authentic requirements derived from PBL projects created favourable conditions for students to develop the skills intended for them through their achievement of CLOs. In particular, the majority of CLOs assessed the ability of students on project management skills through presentation, reports, peer evaluation and showcase that met requirements stated in the rubrics. According to the assessment results, students' performances provided solid evidences that they were able to meet the CLOs stated earlier. For specific CLOs related to the SEPM course, IT students were able to apply appropriate methods to their projects, which were at operational level. Moreover, the teachers' teaching journals revealed that Engineering students' communication-related CLOs were also met as they successfully coordinated teamwork, and presented their projects to the industries and other students at the product showcase. The online survey showed that both group of students (IT and Engineering) expressed overall positive learning experience. The students reported that they were intellectually stimulated during the course, which proved to support students' cognitive processes and thus enhanced self-learning and responsibility. This motivation created opportunities for students to actively search and process new information and connect it to their current understanding of the subject matter (Behizadeh, 2014; Chua, 2014; Musa, Mufti, Latiff, & Amin, 2012) rather than "passively receiving" knowledge**.** Moreover, learning from peers was highly appreciated in the interview where junior Engineering students showed interest in gaining knowledge of various programming languages, and developed complex software systems with the assistance of their IT partners. On the other hand, senior IT students, with the consultancy of their Engineering peers, explored the integration of multiple hardware components, developed software for these and had opportunities to practice leadership skills thanks to the PBL environment. Finally, in the course reflection, the lecturers supported this course setting as they confirmed that the students seemed to inquire much on the details of materials and effectively used lecturers' feedback in assessment items for improving their performance.

Lessons from interdisciplinary coordination

Despite general success of the course, a number of challenges were observed and reported from the interdisciplinary environment. The students rated the collaborative teaching lower than lecturers' expectation. It was only because students experienced confusion when they received significantly different feedback for their work from each lecturer. This problem is also reported by Dugan and Letterman (2008). It could be explained by the fact that the two lecturers had different individual expectations for the quality of work and for the student's performance in two disciplines. This confusion was acknowledged by the lecturers after some discussions with the students regarding the second assessment in week 8 and later was addressed during the delivery by clarifying and aligning expectations for students' work around the middle of the semester. To avoid similar problems, course coordinators should have reached consensus on the similarities and differences of their expectations for students of each discipline before conveying them to students. In case there are unique requirements for different courses, lecturers should split them when announcing their expectations to avoid confusion in the mixed-major class. This information should not only be dispensed at the beginning of the course but also be reiterated and emphasized throughout the course duration.

Even though it was well considered during the course development, the difference between student's levels in groups still raised many challenges to the course delivery. It has been justified that in collaborative groups, to realize their common goals as well as actions, individuals are expected to hold joint authority, responsibility, and acceptance of each other's strengths and weaknesses (Laal & Ghodsi, 2012). However, discomfort was instilled in senior team members because it was brought to the lecturers' attention later during the course delivery and tutorials that there were incidents when junior Engineering students in some groups were not able to carry out their discipline-specific tasks. Their IT teammates, therefore, had to cover the undone hardware-related tasks left by their less capable teammates. As a result, senior students commented that having junior team members hindered the team progress and considered it a challenge difficult to cope with. This happened even when the lecturers constantly gave feedback on students' performance and guidance to assist them in solving their problems. Fortunately, that experience did not discourage most students from expressing their interest in participating in such mixed projects in the future. However, to ensure a more successful course, it is advised for lecturers to organize cross team exchanges, or even a technical tutor to help the first-time PBL learners troubleshoot their obstacles to better catch up with the common pace of the whole team of mixed disciplines and capabilities.

Conclusions

The study has demonstrated CLOs alignment, course structure, and assessment scheme of the PBL interdisciplinary courses for students of IT and Electrical Electronic Engineering majors with collaborative teaching. It also proved positive attitudes from students who asserted their stimulation to learn and overall satisfaction with the course. The formation of students teams comprising students of year 1 and year 3 also showed the motivation for learning from teammates and peer-support; however, it also created trouble to somehow ensure the even performance of team members with different background knowledge. The solution to this problem may be assigning technical tutors to help poor performers or encouraged cross-team support through the class online forums. Besides, the study also pointed out the importance of the clear, and if possible, separate announcements of lecturers' expectations to students of different majors to avoid confusion in an interdisciplinary class.

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A new strategy for active learning to maximise performance in intensive courses

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SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

This paper investigates the effect of changing the formative assessment in an intensive introductory Thermodynamics paper offered to students studying towards an Engineering qualification.

PURPOSE

To improve the use of class time of students in an intensive course so that they are better prepared for their exams which occur in close proximity to learning.

APPROACH

A new approach involving a fully rounded experience was implemented to improve use of students' class time. Active learning strategies, and mini-exams were employed. The quantity of formative assessment was increased, and the structure of classes was altered to place the formative assessment immediately after each topic covered.

RESULTS

An improvement to student grades and completion rates was observed compared to the previous instance of the paper. Student feedback towards the new strategy was very favourable.

CONCLUSIONS

The new structure achieved the aim of lifting passing rates, improving participation and preventing procrastination.

KEYWORDS

Intensive courses; active learning; thermodynamics.

INTRODUCTION

This paper describes an innovation in the delivery of an introductory thermodynamics course offered to students studying towards an engineering qualification. The course was delivered in intensive format, across three weeks of study.

Students find it challenging to engage with complex engineering topics in a short period of time, and there is no sizeable study break for pre-exam study. This means that students cannot afford to delay in learning and applying content. Every class must be an opportunity to interact with the content immediately.

The innovation described here involved implementing a new daily structure for the course that attempted to mimic the standard process by which students learn material, apply it, study it and practice it in across a traditional-length semester. The new structure involved integrating the lecture and recitation components to the course to increasing the active learning during material delivery, then allowing students to engage in guided study and open-book formative assessment.

This paper describes the implementation of this innovation. A brief review of the literature on intensive courses is provided, followed by a description of the approach used in this particular class. The results are then presented, and evaluated in the context of the research and the instructor's own critical reflection.

BACKGROUND

Many tertiary institutions around the world follow a teaching format based around the semester. This refers to half a year, from the Latin for six months (Oxford Dictionary, 2017), where typically the course is between 15 and 18 weeks in duration. Courses delivered in a compressed time-frame, generally last less than half this time. Such courses are variously referred to as intensive mode, compressed, accelerated, abbreviated and time-shortened. This paper uses the term intensive courses.

Intensive courses have become increasingly prevalent, as universities become more market driven and responsive to the changing needs of students (Davies, 2006; Daniel, 2000). This would be a concern if intensive delivery entailed a sacrifice of good pedagogy in the interests of revenue-gathering. However there is no compelling evidence that this is the case. Although academics frequently worry about the effect that the shortened time-frame of intensive courses will have on learning quality (Daniel, 2000), most literature finds learner performance comparable between traditional semester-long courses and their shorter intensive counterparts (Kops, 2014; Daniel, 2000; Anastasi, 2007; Hesterman, 2015). Some find an overall positive effect of intensive learning (Kucsera & Zimmaro, 2010; Anastasi, 2007).

The literature identifies that experienced and mature students (outside the 18-22 traditional cohort) tend to prefer intensive courses (Daniel, 2000). In particular, intensive courses work well with those who must balance study with other commitments, such as work or family (Burton and Nesbit, 2008). Students frequently prefer the ability to concentrate exclusively on one subject at a time (Colorado College, 2017; Daniel, 2000); however they can exhibit some resistance initially to the shortened nature of intensive courses, as they feel doubtful about their ability to learn with less time (Burton and Nesbit, 2008; Tatum, 2010). These doubts tend to reduce as their experience with intensive courses increases, particularly for qualitative courses (Tatum, 2010).

Instructors can have mixed feelings about intensive courses. Some doubt the ability to generate deep learning and engagement in a short timeframe, or feel that intensive courses require significantly greater effort on the part of teaching staff to ensure that sufficient learning is achieved (Anastasi, 2007; Daniel, 2000). Hesterman (2015) notes that teacher attributes are essential to the effective implementation of intensive courses: staff should be experienced and enthusiastic about teaching in intensive mode classes. Kops (2014) identifies that teaching staff appreciate the benefits from intensive courses, including the ability to concentrate teaching into shorter timeframes, freeing up larger blocks of time for research. Teachers may also develop a greater rapport with students, as intensive classes extend the length of time spent with students, and usually entail smaller class sizes (Kops, 2014).

At the institution examined in this article, all courses are taught in modules, lasting between three and seven weeks. Students take one course per module. The students enrolled in courses at the institution represent three distinct groups: level 1 students, who are first years, typically between 18 and 20 years of age; level 2 students, who have completed their first year, and may also be undertaking some industry experience, and level 3 students, enrolled in their final year of study, who will be completing required industry experience. The advantage of this modular teaching is the flexibility it allows students who must fit study in between periods of industry experience.

The course described in this article is a level 1 Thermodynamics paper. Students must complete 12 topics in three weeks, with approximately 25 hours of contact time per week. Students sit two exams, and submit one laboratory assignment for the three-week course. Students must obtain at least 60% in each assessment in order to achieve “competency” (a pass) in the course. Students have an opportunity to “resit” the exam that they failed. The “resit” involves sitting a new exam at a later date.

APPROACH/METHOD

Prior to designing the approach for this course, the research into teaching intensive courses was consulted. Two papers explicitly laid out best practice guidelines. The University of Canterbury (Sampson, Brogt, & Comer, 2011) provides a set of guidelines for teaching in the intensive formats, and Kops (2014) looks at best practice for teaching intensive course as provided by highly rated instructors. Based on the advice of these two papers, and consulting other related literature, the following features were considered important for delivery of the intensive course under investigation in this paper.

1. **Fully prepare courses in advance.**

   Compressed courses offer little flexibility for adjustment, as content cannot be shifted around much in the limited time frame. Accordingly, it is important to prepare courses as much as possible in advance of teaching (Burton & Nesbit, 2002; Kops, 2014). Sampson et al (2011) advise that students’ expectations be managed well from the beginning of the class. Students should know what is covered, when and what is expected of them in terms of assignments, study and workload.

2. **Make learning resources readily available.**

   Students should have timely access to all resources (Sampson et al, 2011), ideally fully-prepared lecture notes that minimise the amount of time students need to spend collating their notes (Kops, 2014). The effective use of the LMS is vital here.

3. Use active learning techniques.

As students' attention suffers decrement as time passes in traditional-length lectures (Bligh, 1998), the longer classes in intensive courses are even less suitable to the typical lecture format. Sampson et al (2011) advise the use of active learning formats, and small group exercises and activities to break up the time in intensive classes.

4. Make effective use of formative assessments.

Formative assessments provide a reflection on learning, and feed forward into future learning. They should be well-designed to enable students to see immediately what they understand and what they need to work on (Irons, 2008).

5. Maximise effective feedback.

Intensive courses do not provide much time for students to catch up on material prior to assessment. Therefore, one of the most serious risks for students in intensive courses is not keeping up with the course. This is also a risk for the instructor, as there is similarly limited time for "catch up" tutorial sessions or the provision of other support for at-risk students. Providing regular feedback on learning is therefore essential for the students and the instructor (Sampson et al, 2011)

The level 1 thermodynamics course described here incorporates these facets above in its redesign. Course materials and quizzes were delivered via Canvas. Students were not required to do pre-reading prior to attending class. Assessment for the course was structured with the three graded summative assessments: Exams A and B which were weighted at 33 and 34% of the coursework grade, respectively; and one practical lab, weighted at 33%. There were six non-graded mini-exams, and three non-graded quizzes.

Each class ran for the set number of hours according to the regular modular delivery for the institution. Classes on Mondays, Tuesdays and Thursdays ran from 8:00am-2:30pm, and Wednesday and Friday classes ran from 8:00am to 11:30am. The schedule for one of the weeks is provided in Table 1 below. Students were provided with each week's schedule in advance; however the overall structure for the three weeks was mapped out prior to the module beginning.

Table 1: Week 1 structure.

Week 1					
Times	Monday	Tuesday	Wednesday	Thursday	Friday
	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug
0800-0830	Temperature	Specific Heat and Steam	Specific Heat and Steam cont.	1st Law of Thermodynamics cont.	Expansion and Contraction
0830-0900					
0900-0930					
0930-1000	Tea Break	Tea Break	Tea Break	Tea Break	Tea Break
1000-1030	Pressure	Specific Heat and Steam cont.	1st Law of Thermodynamics	Catch-up Tutorial	Study Break
1030-1100					
1100-1130					Quiz 1
1130-1200	Lunch	Lunch	Lunch	Lunch	
1200-1230					
1230-1300	Tutorial	Tutorial		Tutorial	
1300-1330					
1330-1400	Study Break	Study Break		Study Break	
1400-1430	Mini-exam	Mini-exam		Mini-exam	

Each full day contains a study-break and mini-exam, as in Table 1 above. The aim of this structure was to replicate the standard study structure employed by students in traditional semester-long courses: attend class, apply concepts in recitation-format class (tutorial), engage in private study, and then sit practice tests or exams to prepare for assessments. In a traditional semester, this takes place over the many weeks of a semester, as shown in Figure 1 (a) below.

Hora and Oleson (2017) identify that, in a traditional-length semester, students' study, as a distinct activity from attending class, or completing assignments, typically takes place a few days prior to a test or examination. As intensive courses do not allow for this, it was necessary to compensate for the limited time-frame that students have to reflect on their material in a way that takes advantage of the longer contact hours that the intensive format provides.

Figure 1 (b) above illustrates how each full day of class replicated the learning/applying then study/practice structure. This approach actually reflects an improvement on the structure shown in Figure 1 (a), as study and practice takes place in a guided environment, with instructor input. This enables accurate feedback on students' learning and more effective use of students' time.

As figure 1 (b) shows, the class combined lecture/recitation methods of delivery. This involved interspersing material with problems that students and the instructor solved in an interactive tutorial-type framework. As each sub-topic was covered, one or more relevant questions were asked of the class. Students had an opportunity to solve these themselves, or work in small groups, with the instructor's guidance. This increased the level of active learning in the transmittal portion of the class. Students were then presented with half an hour or so to study their materials, before sitting a "mini-exam", which tested content from the current day via exam-type questions.

Active learning techniques were embedded in this structure. Prince (2004) finds that introducing active leaning technique into lectures enables students to refocus attention and improves retention and recall. The environment for active learning was fully-guided, which is particularly important for level 1 students, whose learning may be compromised in minimally-guided active learning frameworks (Kirschner, Sweller, & Clark, 2006).

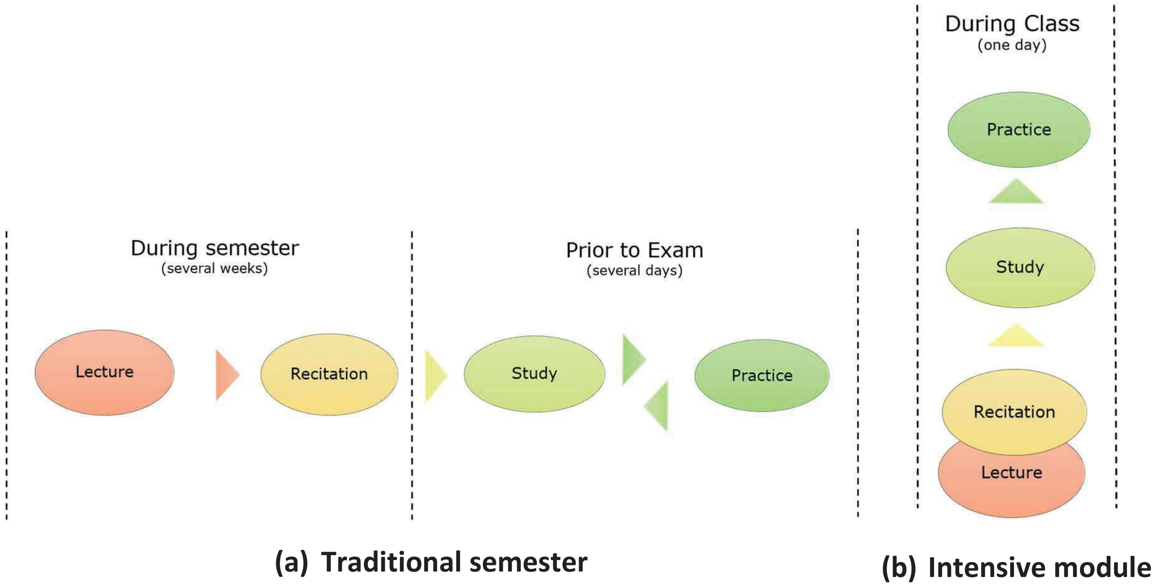

Figure 1: Typical learning and study process for traditional-length semester (a) and in the intensive class (b).

Mini-exams occurred three times per week. This is to gain the advantage of multiple testing effects on retention of material (Crooks, 1988; Tatum, 2010). The shorter time frame for the course increases the risk that procrastination results in a fail. By having multiple formative mini-exams, with moderate stakes, students were not able to delay in familiarising themselves with the material. Although no marks were attached to the mini-exams, the instructor was aware of students' performance and followed up with those who were underperforming. Therefore students had a reason to try harder during the mini-exam, and the instructor was able to monitor performance during the course and address at risk students early.

Tatum (2010) notes the importance of distributed practice and its impact on memory retention. He cites Rohrer and Pashler's (2007) work on optimal spacing between study sessions and testing. The ideal interval between study sessions is between 10% and 30% of the interval between study sessions and the exam. In this course, the exams were spaced between 10 and 12 days apart. The study sessions were spaced between 24 and 48 hours apart, which corresponds to a gap between study sessions of approximately 8-16% of the retention interval for the first exam, and 10 and 20% of the retention interval for the second exam, which is in keeping with the recommendation from Rohrer and Pashler (2007, as cited in Tatum, 2010).

Hesterman (2015) notes that incubation of ideas takes time for students, and suggests that this may be compromised in time-shortened teaching formats. When a problem is set aside for a period, the solution may become apparent during this incubation process (Tatum, 2010). As the time could not be increased, the mini-exams and quizzes attempted to compensate for this. They encouraged students to retain and develop their understanding of the material, including that taught earlier, in order to foster the kind of idea development that is not usually not able to occur in compressed courses.

The continued reinforcement of concepts across the paper calls to mind the spiral curriculum (Bruner, 1960). Although this is typically applied across programs of study (Bruner, 1960; Harden, 1999), single classes can teach their topics in a cohesive "micro"-spiral. As each successive topic is covered, it revisits concepts and skills from earlier topics, builds on them, and demands ever higher processes of thought and problem solving. Developing a cohesive micro-spiral is especially important in intensive courses. Students' mental load increases the more disparate they view the topics (Sampson, Brogt, & Comer, 2011). Continued reinforcement of earlier topics helps students see the interrelationships between topics, and shows them that their knowledge is deepening, as well as broadening.

OUTCOMES

To gain insight into the effectiveness of the new course method, the 2017 passing and completion rates will be compared to the 2016 instance of the course. As a new program, no earlier data exist to make further comparison. Student perceptions will be summarised from the formal feedback, gathered at the course level, as well as inform commentary received during the course. The instructor will also reflect on the experience of modifying the course delivery.

Student performance

Table 2 below compares student performance between 2016 and 2017 for the same paper. The 2016 offering had a similar class size and make-up as the 2017 paper.

Table 2: Changes in pass, fail and did not sit rates from 2016 to 2017

	Pass	Fail (%)	Did Not Sit (%)
Change (2017 compared to 2016)	+ 18.7%	- 7.4%	- 11.3%
Improved / worsened in 2017	Improved	Improved	Improved

As shown above, 2017 saw a marked improvement to all metrics. The number of students passing, rose by 18.7%. The number of students sitting assessments and failing fell by 7.4%. The number of students who chose not to turn up to the exam at all, the Did Not Sit (DNS) outcome, fell by 11.3%.

It should be noted that a DNS has the same effect as a fail for the student. They must undergo another examination at a later date, as they would have done had they sat the exam and failed. Therefore a significant reduction in the effective fail rate (sitting and failing plus DNS) is an improvement between the two instances of the course.

Student feedback.

Students reported that they appreciated the mini-exams and quizzes. Both informal and formal feedback reflected favourably on the continued testing conducted during the course.

Instructor perceptions.

The motivation for this approach arose out of the experience from a similar paper, for a different group of students. When given problems as part of workshops, which followed traditional type lectures, at first students solved the problems by reverse-engineering answers, and performed poorly in free-format problems. This was concerning in an intensive course, as the short time frame limited the amount of time they could spend on the learning curve.

In addition, students always wanted more quizzes and opportunities to practice exams. As the class time was relatively long, the time for private study in the evenings is limited, and there is no reasonable study break between classes and each exam. Some students could be guaranteed to study at home, whereas others may not. Therefore, providing opportunities to practice during class time, in a guided environment, maximised the formative value of each quiz and mini-exam.

Performance during the formative assessments in this course revealed some students to be “at risk” at the beginning of the module. Those who regularly participated in the formative assessments lifted their performance markedly during the module and had a successful outcome at the end. As the theory-application-study-practice structure was employed, students began to perform better in solving more varied problems. As this is the skill required in the graduate profile (solving complex and unexpected problems), an improvement to such skills demonstrated by students is an achievement in the paper.

However, there are some improvements required going forward. There was a small group of students who did not regularly attend classes. Most of these students failed the course, whereas only one of the students who regularly attended class failed the course. Some students noted that they had other commitments, such as work, that prevented their attending class. In future, students should be better informed from the beginning of the module that they should attend all classes. To that end, some online quiz work should be graded. This would encourage students to attend class, and also to attempt more of the formative quizzes as practice for the graded quizzes.

DISCUSSION

The new structure was received favourably by students. The idea of doing exam-type questions as the capstone activity for each full day was very appealing to students. This is unsurprising, as the exams counted for 67% of students’ final grade. Given the position of the mini-exams, and the importance students place on exam preparation, it is worth talking about the potential for instrumental approaches to learning, or “surface learning”, on the part of students. Surface learning refers to the situation where students aim to reproduce knowledge, so as to meet the requirements of a task with minimal effort (Biggs, 1987). Students do not distinguish between new ideas and existing knowledge and focus on material likely to appear in examinations; therefore they may give the impression of extensive learning, but such learning is superficial and soon forgotten (Fry, Ketteridge, & Marshall, 2003; Kember & Gow, 1994). An approach that focuses on the deliverable as the exam may seem to encourage surface learning, as students can be tempted to view learning as valuable only if it has the potential to be reproduced in the exam.

One way to minimise this, and foster deeper learning is to avoid repetition of questions, and make use of a variety of practice problems, so that students do not focus on identifying patterns and formulating study plans based on expectations of what will be tested. As students who have taken the instrumental, surface approach to learning may actually perform well on examinations, it is difficult to tell if the class was focused on surface or deep learning. However, the fact that students moved away from a reverse-engineering approach to answering questions, and began to perform better on a variety of free-format questions, is taken as evidence of better deep-learning.

True evidence of deep learning is retention over time. Students who have actually grown their body of knowledge and skills will be able to recall and employ them at a later date. Therefore one change that must be added to this program is implementation of a follow-up test. This can be a diagnostic test taken in the higher-level Thermodynamics paper to assess the degree to which students have successfully retained the skills taught in the current paper.

The improvement to the passing rate was considered a success; however it is difficult to say whether it is attributable to this change in approach only. The previous year’s paper was taught by a different instructor. It is hard to judge whether approach alone was the reason for the improved passing rate. In addition, as this programme has only been running for the past two years, there are no other years’ papers for comparison, so it is difficult to know precisely the reason for the improvement.

One factor that is a little more obvious is the significant improvement in the completion rate. As DNS (did not sit) results are essentially fails, the reasons for a student electing not to sit the exam are likely similar to their reasons for failing an exam. However there is one key difference: a DNS involves the student not bothering even to turn up for the exam. It is arguable that such an outcome reflects another variable: a profound lack of confidence that sitting the exam will result in a pass. Of course, there may be other reasons, such as illness, that prevent a student from turning up to the exam, but in the presence of automatic rights to “resits”, it is likely that students elect to skip an exam if they feel there is little point in sitting it, due to the likelihood of a fail.

This makes intuitive sense, but little research exists on the true reasons for students not sitting exams. This is because skipped exams often count for zero, and students are aware that lack of preparation is not an adequate excuse for skipping an exam, so tend to proffer other excuses which may be fraudulent (Abernathy & Padgett, 2010; Caron, Whitbourne, & Halgin, 1992; Ferarri & Beck, 1998). Abernathy and Padgett (2010) find that a peak in illnesses and bereavements among students prior to skipping a test can only be attributed to a desire to delay taking that test. Adams’ (1990) slightly tongue-in-cheek assessment of students’ reasons for missing final exams finds a surprisingly strong link between a student’s grade in the course prior to the exam and the reported mortality rate of their grandmothers. Students who are failing a class are 24 times more likely to have a family member die prior to the exam than students who are sitting on an A for the class. The relationship between academic success and excuse fabrication has been found to be significant by Caron, Whitbourne and Halgin (1992), and Roig and Caso (2005). Both studies find that students with higher GPAs report being less likely to fabricate an excuse for missing an assessment.

In the current institution, the availability of a resit makes it easier to miss a final exam and students are not required to come up with an excuse for this. This makes it more likely that ill-prepared students will skip the regular sitting of the exam. The mini-exams worked to address this problem: students received continued preparation for the final exam. Students were informed very early of the areas where they needed improvement, and the consistent use of mini-exams meant they could also track their progress. It is possible that mini-exams could *increase* the DNS rate:

students who receive information that they are not doing well in the course may be more likely to skip the exam than students who did not have this awareness. In the end, only one student did not sit the final examination. Therefore we can infer a link between this kind of course structure and students' sense of preparedness going into the exam. We can also interpret as much from student feedback on the course, where students reported that the mini-exams helped them to prepare for the final exam.

This program also offers a unique opportunity to investigate the reasons for students not sitting exams that other programs do not have. Do to the availability of "resits", students can elect not to turn up to exams without needing to provide a reason. It may be useful to conduct a quick survey of students who are choosing to miss the exam to find out their reason for doing so, as these students will not feel the need to proffer alternative excuses.

CONCLUSION

This paper described the implementation of a new, research-informed, active learning strategy involving replication of the typical learning and studying structure that students tend to follow in a traditional-length semester on a daily basis in an intensive format course.

Students responded well to the altered structure, and were particularly satisfied with the quantity of formative assessment and the level of active learning in the class. Achievement by students in this class showed an improvement for all measures, including passing and completion rates, compared to the previous offering of the course.

The lack of further instances of the course, however, makes it difficult to assess if this change was due to the innovation employed, or other factors. Other factors require further investigation, such as the level of deep learning that has taken place, and the reasons for students choosing not to sit exams. Consequently two follow-up areas for investigation have been proposed.

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Engineering Exposure to Professional Practice Navigating EA, TEQSA, and the Fair Work Act.

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Australian engineering degrees accredited by Engineers Australia at the level of Professional Engineer are required to include the equivalent of 12 weeks of exposure to professional practice. The landscape for this exposure has changed over the past five years with undergraduates finding it increasingly difficult to source the traditional 12 week engineering placement, a changing regulatory environment, and an increased emphasis on constructively aligned learning. This paper presents the salient outcomes from an ACED project funded to explore factors affecting the design of exposure to professional practice activities. It clarifies obligations through the lens of Fair Work Australia, the Higher Education Standards Framework (HESF), and Engineers Australia.

PURPOSE To provide guidance for institutions assessing 'Exposure to Professional Practice' (Industrial Experience) within their engineering curricula against learning objectives, regulatory frameworks and accreditation requirements.

OUTLINE Exposure to Professional Practice (EPP) has been a formal component of Australian engineering tertiary education for many decades. EPP has been a vexed topic across many campuses in recent years as the number of paid (or unpaid) opportunities have reduced due to the variable economic climate. This has led, in some cases, to a disaggregation of EPP and coursework curricula. This could be seen as a lost learning opportunity, which by extension, potentially results in it being perceived as simply an exit requirement for the degree, or at the extreme, a barrier to graduation.

The objectives of EPP within engineering curricula are reviewed as the basis for understanding its value, particularly with regard to increasing the relevance of coursework and aiding transitions to industry. This is used to propose structures and support designed to enhance and assess student learning through EPP.

RESULTS EPP activities can take many shapes and forms. However, EPP activities which occur in industry must be undertaken within the given regulatory environment. For Australian engineering programs, an EPP process map is presented to inform EPP design and the associated use of placement management systems (e.g. in-house, SONIA, InPlace). This map has been designed to align EPP activities with learning outcomes, and therefore may have application outside of Australia.

CONCLUSIONS The design of EPP activities requires consideration and navigation of multiple objectives and requirements. For EPP activities to be effective, integration within the boarder curriculum is essential. The outcomes of the ACED project have enabled guidance material to be developed to support the design of EPP activities.

KEYWORDS WIL, Engineering Industrial Experience, Exposure to Professional Practice

Introduction

Exposure to Professional Practice (EPP) has been a long standing requirement of accredited engineering programs in Australia. The objective of this exposure is to help couple the University delivered theoretical content with contemporary practice experienced across a diverse employment sector. The connection between practice and theory is intended to encourage student engagement with the theoretical content more strongly, providing better graduate outcomes. Further, learning gained through periods of workplace experience enable ‘fresh from school’ students to transition into the workforce with a stronger work ethic and more realistic employment expectations.

In recent years, economic downturns have reduced the volume of paid placements, and uncertainty with the Fair Work Act have led to a reduction in unpaid placements. A national working party was initiated in 2014 at the AAEE Assistant Deans of Teaching and Learning meeting, to investigate practices across the sector. The Australian Council of Engineering Deans (ACED) later requested this group to assist in re-writing the EPP element of the accreditation document ‘G02’, and asked the team to develop a set of appropriate EPP learning outcomes. As this work was nearing completion, the Tertiary Education Quality and Standards Agency (TEQSA) released a consultation draft of the eight page Work Integrated Learning (WIL) guidance note (TEQSA, 2017a) for comment and implementation. This was reported at the AAEE2016 conference in a workshop, and discussed at the post conference AD TL meeting. The ACED backed EPP project team then worked to assess the potential impacts and provided feedback to TEQSA. This feedback is now reflected in the latest version of the TEQSA WIL guidance note (TEQSA, 2017a).

This paper provides an overview of the outcomes from the EPP working party, with the salient aspects of the Fair Work Act, the influence of the TEQSA WIL guidance note, and provides initial comments around the references to sections of the Higher Education Standards Framework from the TEQSA WIL note.

Exposure to Professional Practice ≠ Time in Industry

The majority of Australian undergraduate engineering programs have required a 12 week pre-graduation ‘exposure to professional practice’ for many decades. A number of engineering programs overprescribe/simplify this requirement to require graduands demonstrate 12 weeks of ‘time in industry'. This is not the specific requirement by Engineers Australia. EPP is intended to compliment and thread through the educational process, and whilst periods ‘in industry’ generally contribute to this goal, other mechanisms are cited in the accreditation manual. Examples include ‘real world’ problems, guest industry lectures, site visits etc. The perceived difficulty with these is one of an accounting issue. What is the equivalent numerical ‘value’ of a site visit, or a 1 hour guest lecture?

Consider an imaginary engineering faculty, the irregularities arising from one program ‘claiming’ to have fully embedded EPP and another program claiming zero embedded EPP might easily lead this faculty to ease program management and adopt a blanket approach requiring 12 weeks of ‘time in industry’ to ensure students in all programs gain adequate EPP. There is no denying that in terms of work readiness, that a substantive period of good quality industrial experience prior to graduation will provide students with a valuable and saleable skill. Whilst this is often cited as the Gold Standard, some experiences are expected to be far better than others.

EPP Learning Outcomes and an Exemplar Learning Journal

The EPP project developed three generic Learning Outcomes, or Competency Elements, to focus student’s expectations from EPP, and assist providers in approving/developing EPP experiences. These high level learning outcomes, shown in Table 1, can be met by students at all stages of their study program, and are considered suitable for the diversity of EPP implementations and potential student experiences. These statements are structured in a similar format to the Engineers Australia stage 1 Competency Standards (Engineers Australia, 2013) with the learning outcomes including potential indicators of attainment. These are intended to enable students to focus their reflection on all episodes of exposure to professional practice. Operationally, students would complete an approved EPP activity, and on completion create a descriptive narrative encompassing the experience. Based on that narrative, students would then reflect on the various EPP/EA Competency Elements as appropriate to that experience. This creates an opportunity to request students consider the Degree learning outcomes as part of this reflection process, to encourage deeper program level reflection. A truncated section from the full learning journey document is provided as the concluding page in this paper. This is not presented in expectation for widespread use or deployment, merely as one of a myriad of options to aid students in maximising their personal gain from EPP activities. The format, structure and expectations for the journal are anticipated to be defined by individual providers.

Table 1 – Proposed Learning Journey – Exposure to Professional Practice elements only

REFLECTION AREA	**Exposure to Professional Practice**
COMPETENCY ELEMENT	POTENTIAL INDICATORS OF ATTAINMENT
Exposure to an industrial/technical environment in order to appreciate the various activities associated with engineering practice	Routine, punctuality and maintained work ethic
	Professionalism – integrity, honesty, respect and confidentiality
	Communication with colleagues, experts and laypeople
	Appreciation of the relevance of the engineering curriculum
	Understanding of the influence of professional engineers and the inherent associated responsibility
Observe and undertake tasks in practical aspects of investigation, design and construction of engineering works as a complement to theoretical studies	Understand of the supporting social function that engineers provide.
	Appreciation that every engineering discipline spans a breadth of knowledge beyond the specific curriculum
	Appreciate that a team of people are often required to complete any project
Gain confidence to take up positions that require responsibility, motivation, decision making and communication over other people in the market place	Appreciation of the knowledge gained during studies and the value this adds to you as a prospective employee.

It is the authors' intent, to empower students to create and monitor their own specific learning journey, and in doing so presume that each and every student will present a notionally different aggregation of experiences in demonstration of their 12 weeks (equivalent) of EPP.

EPP activities and suggested aggregation value

Whilst not intending prescription, the Engineers Australia accreditation documentation (currently under revision) will includes a number of activities that EPP might utilise. Some of these activities can be leveraged and generate additional value add through the application of reflective practice. For example, a 1 hour ‘EA’ Continuing Professional Development (CPD) attracting seminar, might provide a student with a demonstrable claim for 4 hours “EPP”, through writing a brief narrative about the presentation and reflecting how that aligns with areas of professional practice and the Stage 1 competencies. Likewise, a ½ day site visit might enable a claim for 1 EPP day through the generation of a narrative and reflection. In these cases, the ‘value’ attributed is expected to be greater than the students expended time.

Each of these activities would constitute a ‘leaf’ in the students learning journey that could be submitted as a portfolio of aggregation for graduation approval. The exact weightings for various activities are left to the individual Universities to develop as appropriate for their situation.

As suggestions, many students are actively engaged in major student led projects, Formula SAE, Robot X, Solar Car challenge, RoboCup, etc. Many of these require student led teams, and therefore a student leader. The student leader in many instances will demonstrate significant levels of the ‘Professional’ attributes aligned with periods of EPP. A narrative and reflection on these episodes should attract due recognition as appropriate for the specific project. Whilst project & team dependant, all members within a team could make an independent claim for hours associated with EPP.

Many programs draw problems from industry and thread these throughout the degree program. Whilst many academics may do this as a natural element of course (unit) design, this is not necessarily factored into a student’s aggregation of EPP time. It is perhaps not uncommon to have complete units presented by industrial conjoints bringing a wealth of inherent EPP and requiring students to complete assessments based directly on industrial problems. In a typical course requiring 140 hours of student effort, taught exclusively by an industry conjoint, is it unrealistic to equate this to 3 weeks of EPP time?

Government regulations

The Fair Work Commission and the Fair Work Act

The Fair Work Commission was initiated in 2009 as part of the Fair Work Act (2009), a government initiative to rationalise and unify oversight bodies and generate a consistent set of guidelines for all Australian workers. The objective of the Act is to provide a balanced framework for cooperative and productive workplace relations. Of relevance to student placements within Higher Education, there are two fact sheets: Unpaid Work (Fair Work Ombudsman, 2017a) and Vocational Placements (Fair Work Ombudsman, 2017b). These fact sheets provide an interpretation of the Act for reference by both Higher Education providers and placement providers.

The Unpaid Work fact sheet provides guidance on where and how a person might complete a short period of unpaid work as demonstration of capacity and/or fitness for duty, but also provides guidance to ensure that this is not exploited. The Vocational Placements fact sheet is aimed at students with an educational requirement to complete a period (or periods) of Work Integrated Learning/Professional Practice as part of their course of study. This document provides an explicit examples for an engineering placements as part of a degree program.

> *“Jayne is in her final year of a mechanical engineering degree and has completed her formal class studies.*
> *As a requirement to graduate, Jayne has to organise professional engineering work experience at a business for 12 weeks. While Jayne has to organise the placement herself, the University has strict criteria about needing to assess an employer to ensure her vocational placement provides the relevant learning environment, and gives final sign-off on the placement. As this arrangement meets the definition of a*

vocational placement under the FW Act, it can be unpaid." (Fair Work Ombudsman, 2017b)

One element that has been misinterpreted within some higher education providers is the productivity element for students on placements. The Unpaid Work fact sheet states:

"Although the person may do <u>some</u> productive activities during a placement, they are less likely to be considered an employee if there is no expectation or requirement of productivity in the workplace." (Fair Work Ombudsman, 2017a)

The misinterpretation has been that students can not undertake an unpaid placement as part of their required EPP, if they complete productive work. Whilst very short periods of work shadowing might be of benefit, longer placements, such as the 12 weeks required by most Universities, a work-shadowing only experience is unlikely to add value to the degree program or meet the objective of EPP.

The authors note that arguments might remain about the potential for exploitation of students. Though, a placement is only considered a vocational placement until the course/program requirement has been met. Therefore, if a program requirement is 12 weeks, work beyond the 12 weeks would not be considered as a vocational placement and, if unpaid, would need to continue to meet the conditions for unpaid work. In engineering the types of experiences sought and the liability/indemnity issues perhaps reduce the potential for exploitation of students.

TEQSA WIL Guidelines

The Tertiary Education Quality and Standards Agency was established in 2011, *"TEQSA regulates and assures the quality of Australia's large, diverse and complex higher education sector"* and *"TEQSA registers and evaluates the performance of higher education providers against the Higher Education Standards Framework - specifically, the Threshold Standards, which all providers must meet in order to enter and remain within Australia's higher education system." (TEQSA, 2017b)*

Through the Threshold Standards and the Australian Qualifications Framework, a significant volume of work has been completed by Higher Education providers in demonstration of compliance. TEQSA guidelines are now a core consideration in the tertiary sector for many decisions and proposals.

In August 2016, TEQSA released their eight page draft guidance note for the inclusion of WIL in programs, notionally for implementation from 1 Jan 2017. This guidance note outlines expected standards for WIL, to ensure that it is constructed as an effective and positive learning experience integrated into the program of study.

In broad terms, the WIL guidance note defines a minimum standard of accountability, and duty of care, for education providers to ensure that a three-way understanding of placement intent exists. The three parties being; the education provider, the experience provider, and the student. Clarity of the student learning outcomes are expected to be provided to all parties to ensure maximum educative value from these placements. The TEQSA WIL guidance note obligates tertiary providers to engage strongly with placement providers and to assure the quality of the placements provided. This engagement spans the duration of any proposed placement to ensure appropriate on-boarding into the workplace, appropriate activities during placement, mid-placement contact (at least monthly if student is undertaking full time EPP) to ensure student wellbeing, and closure at the completion of the placement. This interaction is aimed both at student and EPP providers to ensure a positive trajectory for experience providers, or a block on further placements if they prove inappropriate.

Whilst it is unable to claim as an absolute, it is anticipated that engineering student placements provided at many 'Engineering' companies will already obtain robust inductions and a diverse range of non-trivial activities, meeting the intent of the TEQSA WIL guidance note. However, the rapid rise of 'start up' companies in the engineering space, and where placements are provided by very small businesses, might require a higher level of vigilance from the University with respect to the Higher Education Standards Framework.

From an engineering perspective, the guidance note reinforces the requirements for genuine oversight of EPP activities while a student is on placement. For providers that leave the students vocational industrial placement completely for the student to arrange, a review of their EPP oversight structures may be necessary to remain compliant with TEQSA.

Higher Educations Standards Framework Requirements.

The TEQSA WIL guideline explicitly picks elements of the HESF as requiring specific consideration. These are replicated here for reader convenience and an author interpretation of their impact provided. These interpretations have NOT been tested with TEQSA.

> *"The Standards that are primarily concerned with quality assurance of work-integrated learning delivered through third parties are in Section 5.4 (at Standard 5.4.1). However, the role of work-integrated learning more broadly and the extent of its integration are also related to Learning Outcomes and Assessment (Section 1.4), including, for example, learning outcomes for employment (e.g. Standards 1.4.2c & d). The Standards on Course Design (Section 3.1) are also relevant in so far as workplace learning is adopted and integrated as part of a course of study.*
>
> *Depending on the nature and extent of workplace learning involved, the Standards on Staffing (Section 3.2) may be applicable as well in relation to supervision of students in the workplace. The Standards on Learning Resources and Educational Support (Section 3.3) may equally be applicable, as may those concerned with Credit and Recognition of Prior Learning (Section 1.2) where previous WIL may lead to credit for prior learning.*
>
> *In some workplaces the wellbeing and safety of students (see Section 2.3) may assume particular significance, such as exposure to potentially stressful circumstances in clinical placements. At a more overarching level, the provider's course approval and monitoring processes (Sections 5.1 and 5.3) would be expected to consider WIL."*

Section 1.2 'Credit and Recognition of Prior Learning'. The main elements or this clause are-

> a) *students granted such credit are not disadvantaged in achieving the expected learning outcomes for the course of study or qualification, and*
>
> b) *the integrity of the course of study and the qualification are maintained.*

Overall, the granting of EPP exemption on the basis of previous to study experience is unlikely in engineering education, as there are very few perceivable instances where sufficient exposure to professional engineering practices could occur prior to study.

A partial case is likely where a student with a prior (non-professional) engineering qualification, though upskilling might be able to present a defendable case. It is anticipated that no campus would currently grant a full exemption from the EPP requirements, but enable the student to claim a limited volume of EPP on the submission of a report documenting activities, and preferable reflecting on how these align with the Stage 1 competencies. A tradesman providing a reflection on their trade experience, through the lens of Stage 1 competencies, after completing a volume of academic study, might warrant three to four weeks of EPP?

Where a qualified professional engineer re-enters the undergraduate arena to change engineering discipline, it is likely defendable to grant complete exemption from additional EPP documentation.

Section 1.4 ‘Learning Outcomes and Assessment’ Sections 1.4.2 c & d

This section deals with the appropriate design of courses. Given the nature of EPP, this clause is unlikely to impact on the operation with engineering degrees. Programs that are reliant on ‘entry to practice’ outcomes from WIL, such as teaching and many allied health programs will need to be cognisant of this section of the HESF.

Section 2.3 ‘Wellbeing and Safety’

This is an area where the HESF elaborates that Higher Education providers must facilitate access to an appropriate range of health services and general student support. If a student is taking part in an off-campus period of EPP, it is clear that they are removed from the provision of care that they might be accustomed to. This is a risk to the University that must be managed, to ensure that the students’ wellbeing and safety are not compromised whilst undertaking periods of EPP in industry. This is an area that some Universities might need to expend additional energy in establishing and monitoring the EPP providers. At a minimum, Universities cannot now allow students to complete long placements without periodic monitoring of wellbeing. A suggested minimum contact interval of once per month whilst on a full time placement was suggested to TEQSA as part the feedback process.

Section 3.1 ‘Course Design’

As applied to EPP, this requires all parties to understand why students are seeking EPP, and what tasks might be appropriate/inappropriate. The definition of specific learning outcomes for EPP and the suggestion herein of the learning journey are one possible element to meet this requirement,

Section 3.2 ‘Staffing’

3.2.3.c states that educators are required to hold a qualification 1 level above the program being taught. This includes courses therein, and therefore can be extended to workplace supervisors of EPP. However this rule has a relaxation to account for professional &/or practical experience. At a high level, a ‘Chartered’ eligible professional engineer is easily defendable. However, many students will gain significant applicable knowledge from periods of activity at a trade or pre-trade level – e.g. working as a trade assistant. This represents the complexity with the engineering EPP space. Clearly as a trade assistant, the appropriate supervision is a tradesperson, who is likely several AQF levels below our final target level.

Section 5.3 ‘Monitoring, Review and Improvement’

Of significance is a statement in the HESF, and within the WIL guideline, for monitoring the EPP placement providers, and specifically using student feedback as part of the monitoring process to potentially block some poorly performing EPP locations. From this, Universities may need to develop additional formal tracking of student feedback on various providers.

Section 5.4 ‘Delivery with Other Parties’

> *Work-integrated learning, placements, other community-based learning and collaborative research training arrangements are quality assured, including assurance of the quality of supervision of student experiences.*

Section 3.3 ‘Learning Resources and Educational Support’ is unlikely to present a significant issue with the all but universal adoption of LMS systems

Section 5.1 ‘Course Approval and Accreditation - No significant impact perceived

Discussion

EPP within engineering programs is a requirement of accredited engineering programs and can be structured in many ways. Where industrial placements are a component of an EPP structure, it is necessary for a provider to understand both Fair Work and TEQSA requirements. The Fair Work Act enables vocational placements to be unpaid and TEQSA stipulate a minimum level of acceptable intervention from the educational providers to assure that these experiences are meaningful.

Where students partake in paid engineering employment, this falls into an employee/employer relationship with no legal obligation from the higher education provider. Where the higher education provider explicitly brokers the employment arrangement or requires that placement for the student to fulfil the obligations of their EPP requirement, the placement would need to be structured to meet defined learning outcomes and the TEQSA requirements.

The TEQSA WIL guidance note specifies the tracking and monitoring of student wellbeing but does not prescribe how this should be achieved. Due to the number and diversity of engineering placements, monitoring of placements will be most readily be accomplished through the adoption of a suitable software platform. Ideally such systems would maintain consistent records for past and present placements. There are several such platforms available to the market from Australia providers, such as SONIA and InPlace. One package is actively being explored by a sub-set of Australian Engineering schools to more specifically meet the needs of the engineering placement process. Processes and concepts will be shared with the broader engineering community to ensure, as far as practical, a unified national process.

TEQSA does declare a higher level of conformance and interaction for institutions that receive funds for the provision of EPP requirement.

Conclusions

This paper has explored the Exposure to Professional Practice within engineering education, which has been a long standing element for graduation. The paper has shown that the Fair Work Act allows for the continuation of this practice and through the Fair Work Ombudsman's publications, that the requirements are explicitly clarified for a fictitious engineering student. Importantly, clarification that unpaid, 'productive' work is lawful under the Fair Work Act for vocational placements was gained.

In addition to the FWA requirements, the more recently released TEQSA WIL guidance note requires providers to assure the wellbeing of students on placements. It is therefore necessary to ensure the suitability of all placements within EPP to meet designed educational outcomes. Through the ACED supported EPP group, detailed feedback was provided to TEQSA which has been incorporated into the recently updated TEQSA WIL Guidance note.

A set of TEQSA mandated learning outcomes have been developed and presented for potential use with exposure to professional practice (EPP), with indicators of attainment akin to those used in the EA Stage 1 competency documents to aid student engagement.

Suggestions for a small subset of 'hour leveraging' activities, currently being used at several Universities, as a means of encouraging students to make use of the EPP opportunities that are on offer, such as site visits and special guest lectures have been presented. It is suggested that dependant on each specific University, the range of activities will be greatly expanded, and 'hour valued' as relevant to local conditions.

The final outcome from the ACED funded work and this paper is a learning journal exemplar. Whilst each institution will consider their own implementation, the intent is to aid students in monitoring their aggregation of professional experience towards broad learning outcomes. It is also intended to enable deeper reflection towards the Stage 1 Competency Standards defined by Engineers Australia.

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Appendix A - Example of possible student learning journey for recording of their exposure to professional practice

Student Learning Journey Record

Suggested Template for implimentation into a Portfolio System such as SONIA or InPlace

Students are to complete this form, using the indicators of attinment against each stage one competancy as appropriate. For Exposure to Professional Practice, those with the Green stripe are suggested. As a general tracking of progress, all in Yellow. And progress towards degree programs outcomes, Blue. Some campusus have aligned program learning outcomes with EA Stage 1, and therefore the blue section is not required.

Campues Program Learning outcomes - Add as required and specific to your program

REFLECTION AREA	Exposure to Professional Practice	Date of Entry MM/YY : Reason of Entry (Seminar, site visit etc)
COMPETENCY ELEMENT	POTENTIAL INDICATORS OF ATTAINMENT	Self reflection : How am I meeting these at this point in my degree
Exposure to an industrial/technical environment in order to appreciate the various activities associated with engineering in industry	Routine, punctuality and maintained work ethic Professionalism – integrity, honesty, respect and confidentiality Communication with colleagues, experts and laypeoples Apprecation of the relevance of the engineering curriculum Understanding of the influence of professional enigneers and the inhernet associated responsibility	Prepopulate a number of these as examples: *EG Atended a site visit to XXXX Engineering. Enabled better understanding of …..*
Observe and undertake tasks in practical aspects of investigation, design and construction of engineering works as a complement to theoretical studies	Understand of the supporting social function that engineers provide. Appreciation that every engineering discipline spans a breadth of knowledge beyond the specific curriculum Appreciate that a team of people are often required to complete any project	
Gain confidence in your capacity to take up positions that require responsibility, motivation, decision making and communication over other people in the market place	Appreciation of the knowledge gained during studies and the value this adds to you as a prospective employee.	
REFLECTION AREA	**Professional and Personal Attributes**	Date of Entry MM/YY
COMPETENCY ELEMENT	POTENTIAL INDICATORS OF ATTAINMENT	Self reflection : How am I meeting these at this point in my degree
3.1 Ethical conduct and professional accountability	a) Demonstrates commitment to uphold the Engineers Australia - Code of Ethics, and established norms of professional conduct pertinent to the engineering discipline. b) Understands the need for 'due-diligence' in certification, compliance and risk management processes. c) Understands the accountabilities of the professional engineer and the broader engineering team for the safety of other people and for protection of the environment. d) Is aware of the fundamental principles of intellectual property rights and protection.	
3.2 Effective oral and written communication in professional and lay domains.	a) Is proficient in listening, speaking, reading and writing English, including: - comprehending critically and fairly the viewpoints of others; - expressing information effectively and succinctly, issuing instruction, engaging in discussion, presenting arguments and justification, debating and negotiating - to technical and non-technical audiences and using textual, diagrammatic, pictorial and graphical media best suited to the context; - representing an engineering position, or the engineering profession at large to the broader community; - appreciating the impact of body language, personal behaviour and other non-verbal communication processes, as well as the fundamentals of human social behaviour and their cross-cultural differences. b) Prepares high quality engineering documents such as progress and project reports, reports of investigations and feasibility studies, proposals, specifications, design records, drawings, technical descriptions and presentations pertinent to the engineering discipline.	
3.3 Creative, innovative and pro-active demeanour.	a) Applies creative approaches to identify and develop alternative concepts, solutions and procedures, appropriately challenges engineering practices from technical and non-technical viewpoints; identifies new technological opportunities. b) Seeks out new developments in the engineering discipline and specialisations and applies fundamental knowledge and systematic processes to evaluate and report potential. c) Is aware of broader fields of science, engineering, technology and commerce from which new ideas and interfaces may be may drawn and readily engages with professionals from these fields to exchange ideas.	
3.4 Professional use and management of information.	a) Is proficient in locating and utilising information - including accessing, systematically searching, analysing, evaluating and referencing relevant published works and data; is proficient in the use of indexes, bibliographic databases and other search facilities. b) Critically assesses the accuracy, reliability and authenticity of information. c) Is aware of common document identification, tracking and control procedures.	
3.5 Orderly management of self, and professional conduct.	a) Demonstrates commitment to critical self-review and performance evaluation against appropriate criteria as a primary means of tracking personal development needs and achievements. b) Understands the importance of being a member of a professional and intellectual community, learning from its knowledge and standards, and contributing to their maintenance and advancement. c) Demonstrates commitment to life-long learning and professional development. d) Manages time and processes effectively, prioritises competing demands to achieve personal, career and organisational goals and objectives. e) Thinks critically and applies an appropriate balance of logic and intellectual criteria to analysis, judgment and decision making. f) Presents a professional image in all circumstances, including relations with clients, stakeholders, as well as with professional and technical colleagues across wide ranging disciplines.	
	a) Understands the fundamentals of team dynamics and leadership. b) Functions as an effective member or leader of diverse engineering teams, including those with multi- level, multi-disciplinary and multi-cultural dimensions.	

3.6 Effective team membership and team leadership.	c) Earns the trust and confidence of colleagues through competent and timely completion of tasks. d) Recognises the value of alternative and diverse viewpoints, scholarly advice and the importance of professional networking. e) Confidently pursues and discerns expert assistance and professional advice. f) Takes initiative and fulfils the leadership role whilst respecting the agreed roles of others.	
REFLECTION AREA	**Application of Engineering Abilities**	
COMPETENCY ELEMENT	POTENTIAL INDICATORS OF ATTAINMENT	
2.1 Application of established engineering methods to complex engineering problem solving.	a. Identifies, discerns and characterises salient issues, determines and analyses causes and effects, justifies and applies appropriate simplifying assumptions, predicts performance and behaviour, synthesises solution strategies and develops substantiated conclusions. b. Ensures that all aspects of an engineering activity are soundly based on fundamental principles - by diagnosing, and taking appropriate action with data, calculations, results, proposals, processes, practices, and documented information that may be ill-founded, illogical, erroneous, unreliable or unrealistic. c. Competently addresses engineering problems involving uncertainty, ambiguity, imprecise information and wide-ranging and sometimes conflicting technical and non-technical factors. d. Partitions problems, processes or systems into manageable elements for the purposes of analysis, modelling or design and then re-combines to form a whole, with the integrity and performance of the overall system as the paramount consideration. e. Conceptualises alternative engineering approaches and evaluates potential outcomes against appropriate criteria to justify an optimal solution choice. f. Critically reviews and applies relevant standards and codes of practice underpinning the engineering discipline and nominated specialisations. g. Identifies, quantifies, mitigates and manages technical, health, environmental, safety and other contextual risks associated with engineering application in the designated engineering discipline. h. Interprets and ensures compliance with relevant legislative and statutory requirements applicable to the engineering discipline. i. Investigates complex problems using research-based knowledge and research methods.	
2.2 Fluent application of engineering techniques, tools and resources.	a. Proficiently identifies, selects and applies the materials, components, devices, systems, processes, resources, plant and equipment relevant to the engineering discipline. b. Constructs or selects and applies from a qualitative description of a phenomenon, process, system, component or device a mathematical, physical or computational model based on fundamental scientific principles and justifiable simplifying assumptions. c. Determines properties, performance, safe working limits, failure modes, and other inherent parameters of materials, components and systems relevant to the engineering discipline. d. Applies a wide range of engineering tools for analysis, simulation, visualisation, synthesis and design, including assessing the accuracy and limitations of such tools, and validation of their results. e. Applies formal systems engineering methods to address the planning and execution of complex, problem solving and engineering projects. f. Designs and conducts experiments, analyses and interprets result data and formulates reliable conclusions. g. Analyses sources of error in applied models and experiments; eliminates, minimises or compensates for such errors; quantifies significance of errors to any conclusions drawn. h. Safely applies laboratory, test and experimental procedures appropriate to the engineering discipline. i. Understands the need for systematic management of the acquisition, commissioning, operation, upgrade, monitoring and maintenance of engineering plant, facilities, equipment and systems. j. Understands the role of quality management systems, tools and processes within a culture of continuous improvement.	
2.3 Application of systematic engineering synthesis and design processes.	a) Proficiently applies technical knowledge and open ended problem solving skills as well as appropriate tools and resources to design components, elements, systems, plant, facilities and/or processes to satisfy user requirements. b) Addresses broad contextual constraints such as social, cultural, environmental, commercial, legal political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process. c) Executes and leads a whole systems design cycle approach including tasks such as: - determining client requirements and identifying the impact of relevant contextual factors, including business planning and costing targets; - systematically addressing sustainability criteria; - working within projected development, production and implementation constraints; - eliciting, scoping and documenting the required outcomes of the design task and defining acceptance criteria; - identifying assessing and managing technical, health and safety risks integral to the design process; - writing engineering specifications, that fully satisfy the formal requirements; - ensuring compliance with essential engineering standards and codes of practice; - partitioning the design task into appropriate modular, functional elements; that can be separately addressed and subsequently integrated through defined interfaces; - identifying and analysing possible design approaches and justifying an optimal approach; - developing and completing the design using appropriate engineering principles, tools, and processes; - integrating functional elements to form a coherent design solution; - quantifying the materials, components, systems, equipment, facilities, engineering resources and operating arrangements needed for implementation of the solution; - checking the design solution for each element and the integrated system against the engineering specifications; - devising and documenting tests that will verify performance of the elements and the integrated realisation; - prototyping/implementing the design solution and verifying performance against specification; - documenting, commissioning and reporting the design outcome. d) Is aware of the accountabilities of the professional engineer in relation to the 'design authority' role.	
2.4 Application of systematic	a) Contributes to and/or manages *complex* engineering project activity, as a member and/or as leader of an engineering team. b) Seeks out the requirements and associated resources and realistically assesses the scope, dimensions, scale of effort and indicative costs of a *complex* engineering project. c) Accommodates relevant contextual issues into all phases of engineering project work, including the fundamentals of business planning and financial management	

approaches to the conduct and management of engineering projects.	d) Proficiently applies basic systems engineering and/or project management tools and processes to the planning and execution of project work, targeting the delivery of a significant outcome to a professional standard. e) Is aware of the need to plan and quantify performance over the full life-cycle of a project, managing engineering performance within the overall implementation context. f) Demonstrates commitment to sustainable engineering practices and the achievement of sustainable outcomes in all facets of engineering project work.	
REFLECTION AREA	**Core Knowledge and Skill Base**	
1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.	a) Engages with the engineering discipline at a phenomenological level, applying sciences and engineering fundamentals to systematic investigation, interpretation, analysis and innovative solution of *complex* problems and broader aspects of engineering practice.	
1.2 Conceptual understanding of the, mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.	a) Develops and fluently applies relevant investigation analysis, interpretation, assessment, characterisation, prediction, evaluation, modelling, decision making, measurement, evaluation, knowledge management and communication tools and techniques pertinent to the engineering discipline.	
1.3 In depth understanding of specialist bodies of knowledge within the engineering discipline.	a) Proficiently applies advanced technical knowledge and skills in at least one specialist practice domain of the engineering discipline.	
1.4 Discernment of knowledge development and research directions within the engineering discipline.	a) Identifies and critically appraises current developments, advanced technologies, emerging issues and interdisciplinary linkages in at least one specialist practice domain of the engineering discipline. b) Interprets and applies selected research literature to inform engineering application in at least one specialist domain of the engineering discipline.	
1.5 Knowledge of contextual factors impacting the engineering discipline.	a) Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline. b) Is aware of the founding principles of human factors relevant to the engineering discipline. c) Is aware of the fundamentals of business and enterprise management. d) Identifies the structure, roles and capabilities of the engineering workforce. e) Appreciates the issues associated with international engineering practice and global operating contexts.	
1.6 Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the engineering discipline.	a) Applies systematic principles of engineering design relevant to the engineering discipline. b) Appreciates the basis and relevance of standards and codes of practice, as well as legislative and statutory requirements applicable to the engineering discipline. c) Appreciates the principles of safety engineering, risk management and the health and safety responsibilities of the professional engineer, including legislative requirements applicable to the engineering discipline. d) Appreciates the social, environmental and economic principles of sustainable engineering practice. e) Understands the fundamental principles of engineering project management as a basis for planning, organising and managing resources. f) Appreciates the formal structures and methodologies of systems engineering as a holistic basis for managing complexity and sustainability in engineering practice.	

Embedding Authentic Practice Based Learning in Engineering Undergraduate Courses

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C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

CONTEXT Authentic education, which connects the lessons with students' real lives and their prior knowledge, has the potential to create meaningful learning environments in which students see their lessons as meaningful, useful and relevant. Typically engineering undergraduate courses do not provide students with an opportunity to solve meaningful real life engineering problems that are beneficial for their lives and societies. Authentic engineering education has the potential to help students develop their creativity, problem solving and innovation skills.

PURPOSE The focus of authentic education is to employ interdisciplinary ways in order to solve real-world problems. This study aims at inspiring other educators to integrate authentic scenarios into their teaching activities.

APPROACH For this study projects and assignments with real life relevance were introduced for several courses across a semester for students enrolled in papers spanning a range of years and engineering disciplines. Students comments on their learning experience with this authentic approach vs. traditional lecture based teaching are included in this paper.

RESULTS Early observations indicate an increased level of engagement with students more motivated to learn and displaying an enthusiastic positive approach to their study. It is also considerably more exciting and stimulating environment to teach in.

CONCLUSIONS This paper outlines relatively early efforts to change the established learning paradigm in engineering classes and as such it is too early to draw firm conclusions. However, our experiences to date demonstrate that providing a more authentic education environment engages students more positively in their study. Creating such an environment connects theory and practice and exposes students to real life situations and should prepare them better for 21st century challenges.

KEYWORDS Real World Problems, Authentic Learning, Self-Directed Learning

Introduction

The new pedagogical concept called "authentic learning' was proposed by Herrington et al (Herrington, 2006). Authentic learning typically relates to real world, complex problems and their solutions, using role playing exercises, problem-based activities in real or simulated communities of practice. Herod (Herod, 2002) describes authentic learning as follows:

> "*In this type of learning materials and activities are framed around real life contexts in which they would be used. The underlying assumptions of this approach is that material is meaningful to students and therefore, more motivating and deeply processed."*

It is reported that students engaged in authentic learning activities cultivate "portable skills" and develop the flexibility to work across disciplinary and cultural boundaries to generate innovative solutions (Chang et al., 2010).

The process of authentic learning creates an interdisciplinary approach to providing solutions to real life problems that students relate to and are motivated to learn skills that better prepare them better for the Grand Challenges (Vest, 2008) they will encounter in their careers and lives after leaving university (Jadud, 2000).

Typical traditional engineering courses often do not provide students with an opportunity to solve meaningful real life engineering problems that are beneficial for their lives and societies. It has also been around fifty years since the engineering curricula has changed significantly. Since this time science and mathematics has had a central and dominant emphasis in most engineering courses. However much has changed in this time and a modern engineer requires a broader set of skills. In recent years many employers have complained about the need for new engineering graduates to have more professional skills (Miller, 2010).

As Richard Miller of Olin College, USA reports many modern students are highly motivated to tackle the Grand Challenges referred to by (Vest, 2008) but do not see the narrow study of physics and mathematics to be the key to tackling these problems. They are often seeking to make a positive difference in the world and the lives of people. They also do not see the study of engineering science and mathematics as being directly related to the problems that they see or care about (Miller, 2010). Miller argues that engineering curricula need rebalancing and requires students to be more involved in "maker" projects less time spent in lectures that involve learning just in case knowledge about topics that are never actually needed.

Higher education is beginning to shift, but slowly. The old pedagogical paradigm of the expert professor delivering content to rows and rows of quiet students who take notes and prepare to demonstrate knowledge in tests is beginning to change. Now we can see the emergence of more experiential learning in engineering courses worldwide. These developments in engineering education are leading to fundamental changes in curricula and pedagogies (Kolmos et al., 2004)

There is much evidence that instructional strategies that encourage undergraduates to become actively engaged in their own learning can produce levels of understanding, retention and transfer of knowledge greater than those resulting from traditional lecture/lab classes (Lord, 1997), however in many science and technology subjects there has been little adoption of student centric practices (DeHaan, 2005) despite evidence that the "sage on a stage" approach (King, 1993) is not as effective as alternatives. Developments in student-centric learning such as problem-based and project-based learning have so far had relatively little impact on mainstream engineering education (Mills and Treagust, 2003), this could in part be attributed to a lack of understanding of the difference between these approaches, particularly when a project-based approach is mistakenly represented as problem-based. It is not uncommon for project-based approaches to be based around specifications for a desired end product, and such fixed expectations can diminish the learner's role in setting the goals and outcomes (Savery, 2015). Whilst student-centric approaches are gaining popularity in STEM subjects, the liberal arts disciplines were early adopters of such approaches. It has been argued that engineering and technology should be reconfigured as academic disciplines, similar to other liberal arts disciplines (Duderstadt, 2010). Whilst this view is gaining some support many universities and professional institutes remain sceptical and wedded to a more traditional approach.

Traditional engineering instruction is deductive, beginning with theories and progressing to the applications of those theories (Prince and Felder, 2006), whereas arts based pedagogies are more inductive. Topics are introduced by presenting specific observations, case studies or problems, and theories are taught or the students are helped to discover them only after the need to know them has been established. A wide variety of inductive teaching methods exist, including inquiry learning, problem-based learning, project-based learning and discovery learning. The mismatch that exists between common learning styles of engineering students and traditional teaching styles of engineering professors is not a recent observation (Felder and Silverman, 1988) which begs the question, why has there been no widespread adoption of inductive teaching methods in the engineering disciplines? In engineering, the most-favoured pedagogical model for teaching in an inductive style is project-based learning (Dym et al., 2005). Project based learning is an approach to learning that focuses on developing a product or the creation of an artefact of some form. Whilst not formally defined as such, project based learning has the potential to embrace the principles of learning by doing (Schank et al., 1999), though the project may or may not be student-centred, problem-based, or inquiry-based as has been observed by de Graaf and Kolmos (De Graaf and Kolmos, 2003) who define three types of projects that differ in the degree of student autonomy.

1. Task based project: Student teams work on projects that have been defined by the instructor, using largely instructor-prescribed methods. This type of project provides minimal student motivation and skill development, and is part of traditional instruction in most engineering curricula.
2. Project based learning: The instructor defines the subject area of the projects and specifies in general terms the approaches to be used (which normally involve methods common in the discipline of the subject area), but the students identify the specific project and design the particular approach they will take to complete it.
3. Problem based learning: The students have nearly complete autonomy to choose their project and their approach to it.

Much has been written on the third of these, namely problem based learning (Kolmos et al., 2004).

Real authentic learning is a further development of problem based learning. (Grabinger et al., 1997). Authenticity is an important part of problem based learning for three reasons. First, realistic problems hold more relevance to students' needs and experiences because students can relate what they are learning to problems and goals that they see every day. Secondly because students encounter during learning are authentic and reflect the true challenges of real world problems leading to a deeper learning. Thirdly because solutions to really complex problems benefit from a group or team approach that opportunities for the students to the learn communication, collaborative and presentation skills required of a modern engineer.

Students acquire content and skills through the resolution of realistic problems. Understandings that are developed in their realistic and complex situations are more easily retrieved when needed (Brown et al., 1989).

The objective of incorporating work experience into an engineering degree programme is widely accepted as a worthy direction but its application has proved to be quite difficult in practice. Other alternatives include, Gap Year, which provides a year of work prior to education programme starting and can provide a challenging and exciting experience attracting students into engineering.

Another method of integrated work experience is the sandwich degree in which periods of work experience are alternated with periods of study. (Blackwell et al., 2001). Yet despite the advantages of sandwich degrees, there has been a steady fall in the numbers enrolling on such courses. But why don't more universities offer placement years – and in a broader range of courses?

Employers' reluctance to spend time supervising students is partly to blame, says Warwick University professor Kate Purcell (Purcell and Tzanakou, 2016) who also observes that,

"Work placements are very difficult for universities to set up and they're expensive for to run – departments have to arrange visits by academics, and mentoring, to ensure students are having a rewarding experience."

Integrated semesters of work experience where universities utilise a three semester per year system to better utilise their staff and facilities and use the extra semester for work related projects (Blair et al., 2004).

Authentic problem based learning requires a shift in the traditional roles of students and lecturers. Teachers become facilitators and tutors of the learning process rather than presenters of knowledge. Students become self-directed learners and problem solvers (Grabinger et al., 1997).

This paper therefore suggests that a new model of engineering education is needed. Whilst the lecture plus tutorial model has some advantages, the authors experience is that students are turning away from lectures, which they find too boring. They need more flexible ways of learning engineering and demonstrating engineering expertise. This paper draws on experiences integrating such approaches in a broader educational context and proposes a radically different socio-technical and more authentic approach.

Our Experiences

The experiences of the authors of this paper are different. Each has come through an alternative route, either involving a change of discipline, the teaching of engineers in a non-engineering subject or the involvement in teacher training that involves educators from a wide range of domains. Common to these experiences is exposure to different ways of thinking and approaching education that has resulted in a belief that engineering education can be different. In particular, all of the authors feel that the core pedagogic values of the arts disciplines can play an important role in STEM subjects (Connor et al., 2014). These values place the student at the heart of the learning experience and support the student in terms of defining their own learning journey, which becomes a vehicle for introducing disciplinary knowledge. The next section presents case study projects that demonstrate the effectiveness of more inductive approaches to education for engineering and design. These case studies are taken from different schools within the Faculty of Design and Creative technologies. They are taken from varying stages of the curriculum from first year through to final year and masters studies.

Auckland University of Technology (AUT) offers a number of accredited degree options including 4-year Bachelor of Engineering (BE) degrees (aligned the Washington Accord) and 3-year Bachelor of Engineering Technology (BEngTech) degrees (in line with the Sydney Accord), across a range of disciplines, including mechanical, electrical and built environment engineering. In offering these programmes, AUT has framed itself as a contemporary university with a distinctive approach to teaching and learning. It has a vision of providing student-centred, innovative and responsive learning experiences.

Around six years ago we undertook a major curriculum development In line with this vision. The spine of the new curriculum was design based with three group design projects running through the programme. (One of these design projects is included in the case studies). All of these design projects were based around a loosely defined problem that gave the students ample scope to research and consolidate their previously acquired technical skills in a simulated authentic situation.

Developing a new curriculum is quite a challenge, it is a difficult system problem and real complete transformation can only be achieved by having all the following elements satisfied (Kolmos et al., 2004)

- Vision
- Consensus
- Skills
- Incentives
- Resources
- Action plan

We cannot honestly state that all of these have been met fully yet at Auckland University of Technology, however there is certainly a vision and this has been confirmed by substantial investment in new teaching environments including ‘maker’ spaces and collaborative spaces similar to those students will experience outside of university.

Most of the academic staff have been open to change and have responded positively. There are some staff that are a little resistant and continue to ‘teach’ in outdated fashion.

More could have been done to prepare academic staff for the transformation but programmes are now in place to develop the additional skills required. All new academic staff are required to undertake some education training within the first two years of joining. Workspaces for new student centric teaching have been provided with more currently being built.

In terms of human resources it is fair to say they have been stretched. Ultimately more authentic problem based learning should, in time, free up lecturer capacity previously used in third and fourth year lectures and tutorials. So far this has not been evident.

It has been common practice in most engineering degree programmes to have a final year project but most of the teaching up until the final year had been subject based with students answering artificial text book questions style questions. The authors of this paper decided to experiment with using authentic case studies immersing students in realistic situations that could encourage a deeper learning. The rationale behind this approach is based on work by (Jonassen, 1999) who described a model for a learning environment based on constructivist principles, which provides a framework for using cases to support authentic activities. The model centres on a focal learning activity, which may be a project, problem or case the learner must solve or resolve.

(Anderson et al., 2014) argue that a case study method of teaching develops students’ critical thinking skills. (Montpetit and Kajiura, 2012) argue that “*Case based authentic teaching and learning strategies can offer instructors effective pedagogical tools to scaffold learning through activities designed to fulfil teaching objectives and desired student learning outcomes”*

(Anderson et al., 2014) however do have some reservations and highlight that these methods can be “scary and challenging” for instructors and also that they can time consuming and more work initially than traditional lectures. Our experience has been that whilst the initial work in researching and setting up authentic cases increases, the time spent in formal lectures has decreased and student motivation to learn has increased.

The following case studies highlight a number of ways that cover the same skills to be learnt but in a more authentic way.

Case One Engineers Without Borders (EWB)

The EWB project is part of the 'Introduction to Design' course which is a core course for both the Bachelor of Engineering Technology and Bachelor of Engineering (Honours) degrees first year first semester at Auckland University of Technology. The course develops effective communication skills in an engineering design context, using a variety of media. It further develops an understanding of the role and responsibilities of an engineer in society. The pedagogy used for this course is different to that of traditional engineering subjects where students passively receive information from the lecturer. Overall the approach is one of active learning. The design element is essentially covered by students completing tutorial problems individually or in groups with the aid of a facilitator, essentially a variation on the studio-based learning approach. The EWB Challenge could be considered either as an authentic project based learning, problem based learning or inquiry based learning. Certainly, it is intended as a project based learning framework driven by a poorly defined problem statement. However, for most of the groups this authentic problem based learning stimulated a deeper engagement that enabled these teams to transition in to an inquiry based learning mode as their interest and their commitment to the project developed. Certainly, the groups were encouraged to develop their projects in this way. Given there is general confusion about project based learning and problem based learning, this case study provides a useful opportunity to clarify how the various approaches are related. We consider problem based learning to be a subset of inquiry based learning, which itself is a subset of active learning (Spronken-Smith et al., 2008). However, not all problem based or inquiry based approaches are necessarily project based learning. Project based learning is another subset of active learning that overlaps with problem based learning. The EWB Challenge is a fantastic opportunity for students to learn about and understand different cultures and be involved in an exciting time of change for the region selected for that years challenge. A previous challenge was based on a rural hill top communities in the Gorkha District of Nepal. It presented an opportunity to learn, not just about the challenges facing their communities, but also about community development in general, and the role engineers and other technical professionals can play. Engineers without Borders (EWB) is working towards the goal of a transformed engineering sector so that every engineer has the skills, knowledge, experience and attitude to contribute towards sustainable community development and poverty alleviation. The EWB Challenge program aims to contribute to this broader goal by working at the university level to create change within engineering curriculum and help to shape future engineers by achieving the following objectives:

- Introduce first year engineering students to concepts of humanitarian engineering by working on real world development projects.
- Empower university students to gain an increased awareness of the role of engineers in poverty alleviation and their individual responsibility as global citizens.
- Support EWB's community based partner organisations work by providing access to engineering student design ideas and by supporting them to share knowledge and resources with universities internationally.

The students were asked to form groups of four and select a design area for their project. Design areas included but are not limited to housing & construction, water supply & sanitation systems, energy, waste management, climate change, information & communications technology or transportation. The groups provided design solutions for projects using the village of Sadhikhola as a case study. They could address a single issue or provide an integrated design solution for two or more areas, or even propose an alternative project. The EWB Challenge is an open-ended learning experience and the breadth and depth of design is left to the groups to decide. Throughout the project students were encouraged to be creative in their solutions and to document any assumptions in the final report. The project based learning activity was assessed in two ways. Firstly by a group presentation in which all members were expected to participate fully and secondly by way of a project report. A single group mark was awarded to all group members. Where a group member had not participated fully their mark was adjusted accordingly. Around 100 projects were completed. All were of good standard, some were exceptional. Some groups and individuals were extremely well motivated and developed valuable research skills preparing them well for life-long learning. Most of the students achieved learning outcomes that included critical thinking, ability for independent inquiry and the responsibility for own learning and intellectual growth. While no evidence proves that problem based learning enhances academic achievement as measured by exams, there is evidence to suggest that problem based learning "works" for achieving other important learning outcomes. Studies suggest that problem based learning develops more positive student attitudes, fosters a deeper approach to learning and helps students retain knowledge longer than traditional instruction. Further, just as cooperative learning provides a natural environment to promote interpersonal skills, project based learning provides a natural environment for developing problem-solving and life-long learning skills (Kolmos et al., 2004).

Case Two Authentic Design Based Learning Project Conveyor Belt Design

Here students were required to self-assign into teams of four, similar to what would be typical in a real life design office. Workspace office with computers etc. was made available to the students, again to simulate conditions that would encounter outside of university.

"Working as a team of four students, you are to assume the function of an engineering design company tasked with undertaking this design project. The client, the Salty-Dog Ltd, is located directly adjacent to the fishing wharfs at Castle Point and processes the brine-stored catch into a range of tasty products for export consumption into twelve countries. This company have requested that your design consultancy provide the fully detailed design for a continuous slat conveyor to transfer pallets of fish in brine from the loading bay into the fish-finger and whole fish fillet processing departments. These pallets are loaded into the conveyor and removed from the receiving table by hand. Your team's task is to design the power transmission system and supporting structures for the conveyor from prime mover to the head shaft and conveying medium. For the purposes of this project, the assembly drawing of the drive system may be schematic/pictorial, but the head-shaft drawing and means of bearing support must provide sufficient detail to enable manufacture of the shaft by a contract engineering shop. Detail of the supporting structure and guarding of the drive system is also required and consideration should be given to the conveyors operating loads and conditions during the design process as well as design for quality and reliability. The design report should be professional in its presentation to the customer and should include specifications of the drive system, supporting structure and a summary of supporting calculations for the design referenced as appropriate".

This project is an excellent illustration of how authentic problem based learning can replace the traditional lecture/tutorial model. The level of technical skills alone would have included advanced materials, advanced strength of materials and Computer Aided Design. Previously students would have generally been happy to just study enough to pass tests and examinations. Now they are motivated to learn and in a much deeper way.

In addition to the technical aspects of the project there are softer skills being acquired. The project requires an understanding of environmental, Social, ethical and legal requirements. Furthermore the requirement to work in a group promotes collaboration and communication skills that employers often say are lacking in engineering graduates.

Authentic assignments and situations

It is not necessary that all teaching be of the larger authentic project type. Many of the staff now frame questions or mini assignments in authentic situations replacing dry text book style questions with real situations that contain the subject skills to be acquired by the students. We cannot claim this to be a universal approach as yet but this is a growing trend. Two example case studies are used where the student is placed in the role of engineer/designer in an authentic work situation.

Smart Materials Assignment

The subject of so called SMART materials was previously covered in two separate papers. Advanced Production Systems and Advanced Materials by way of lectures. Both papers were taught separately and no effective link was made between the properties of these type of materials, how they could be manufactured in the future, sustainability issues and commercial possibilities.

Again students typically would try to remember only enough to 'get through' both papers. This assignment places the student in the role of engineer who has to investigate and report formally to their CEO.

Put yourself in the role of a Project Engineer of a fictitious Company. This Company can be based on an existing Company that has developed 'Smart Materials' into a product.

The CEO of your Company has heard something about these 'these so called smart materials'. He has little understanding of what they are and how they might benefit your Company. [Choose an Industry or Company]

He has asked you to prepare a report that explains what they are and how they could be used in future products for your Company.

Give details of the material properties.

You are asked to detail the possible applications applicable to your Company or Industry and the benefits they could bring.

You are expected to detail materials and processes involved.

You are expected to consider 'design for sustainability issues'

You should make recommendations on possible development of 'Smart' materials in your particular Company.

This should be produced in report format and be no more than 2000 words.

Case Four Design for Disability

The Design for Disability project is a semester long project undertaken by second year students majoring in mechatronics and is the backbone of the second year Mechatronics Design class. The class is designed around the observation that attempting to define mechatronics as simply the combination of different technologies is no longer sufficient to explain mechatronics and that in reality mechatronics solves technological problems using interdisciplinary knowledge. Rather than focusing on mechatronics from the bottom up combination of components, the class adopts a top down approach that focuses on systems engineering approaches and design thinking.

The Design for Disability project is open-ended, ambiguous and exhibits all of the characteristics of a real world design problem. Student teams are simply asked to design something that can improve quality of life for people with disability and are expected to undertake suitable problem framing (Dorst and Cross, 2001; Sosa et al., 2017) to not only define disability and quality of life, but to also provide an insight to potentially creative solutions. For example, students are encouraged to think beyond approaches to assistive living and instead consider projects that encourage societal change. Whilst not undertaken by students, an example of such a project would be a wheelchair simulator incorporating virtual reality technology to allow able-bodied people to experience the frustrations of being in a wheel chair as a means to change perceptions around disability.

The project aims to balance activation of students' creativity with systematic systems thinking and engineering design practice by leading students through periods of divergent and convergent thinking. The initial problem framing, essentially a creative activity, is immediate followed by the development of a formal requirements specification that embodies both user requirements and system requirements as a starting point for design activities as well as to encourage downstream activities relating to verification and validation of design solutions.

The assessment for this class has also been structured to be balanced across the three concepts of knowing, thinking and doing. The most significant assessment is the use of a blogging platform to record a design journal that shows the processes used to reach a solution to the brief, the rationale for all design decisions as well as to capture individual reflections on both the designed product and the design process.

At the time of writing, this first delivery of this class is still incomplete. However, positive student engagement with the delivery has been noted with high attendance and a large degree of interaction between staff and students that is verging on becoming an exercise in co-creation. Whilst some students had initial reservations on the ambiguity of the brief, others immediately accepted the different approach with comments on their blogs such as the following two observations:

> *"The structure of this paper was not expected but appreciated. It is refreshing to be in an environment that wants to change the norm; given that my aim is to be an interrupter, not just an innovator."*

> *"This class is the most exciting class in engineering so far. Mostly because we will be asked to embrace out creative side instead and not focus on the physics and the equation part of it. It will also challenge our perceptions of the role of the engineer in solving complex, open ended problems."*

In terms of successes to date, the class has successfully engaged students in an open-ended design task, however despite this success there is still room for further improvement. Whilst the design brief specifically encouraged teams to think beyond assistive living, there seems to have been some reticence on the part of the student teams to push the boundaries of the brief with all teams choosing to frame the problem in such a way that it produces an assistive device as an outcome. This is potentially as a result of a lack of confidence or concern over how a less orthodox framing could be received which is a potential disconnect from the intention to develop new "modes of thinking" that shift the traditional focus from teaching-by-transmission to a more socialised engagement with learning through creativity, collaboration (Connor et al., 2015).

Whilst the class has produced a high degree of engagement with the student cohort, there have been difficulties with the delivery particularly in terms of the effort required to maintain a robust and useful dialogue with the student teams through the project work. Arguably, the constant critique of student work through the online design journal would not scale to the large class sizes often associated with many first year classes.

Results and Discussion

There has been curriculum change that has resulted in design projects being at the core and running through the whole period of the degrees but much of this is not yet authentic learning. It is an improvement on the traditional curriculum but has not really gone far enough. This requires a change in mindset of academic staff and ideally is supported by a top down vision and support. However as identified by Kolmos et al. (2004) these changes are difficult and take time. It may need a different approach to academic staff recruitment with a change in emphasis from employing PhD research biased academics to some with real world experiences.

The case studies discussed in this paper indicate that a ‘bottom up’ approach can show immediate benefits. The authors of the paper did not wait to be told that they must change their approach to one of authentic learning.

This change in approach has been received favourably by students are shown by student comments in case four and also the following comments from final year student who has been with us as our approaches to course delivery have changed.

We are sure that our students are now graduating with an improved skill set that better equips them for their engineering careers than previously.

“During my time at University I felt that most courses assessed me in very much the same way. This was to set questions and exercises that immediately utilised an idea. Which was albeit a valid method to force a rule or concept into my head, however it always felt like after the course was over this information didn’t stick very well. My experience always felt like one task after another, to be completed, assessed and forgotten. In my experience the real life projects where I am given more freedom and agency to pursue a solution are enjoyable and I feel what I learned has stuck” [Final year BE Hons student]

Conclusions

It is too early to draw firm conclusions but our experiences to date suggest that providing a more authentic education environment has the potential to engage students more positively in their study. Creating such an environment connects theory and practice and exposes students to real life situations and should prepare them better for 21st century challenges.

Based on our anecdotal observations, it appears that authentic learning is allowing our students to relate target learning effectively through concrete experience and collaborations. Similarly, it appears that this approach motivates students in learning and provides an opportunity for students to use what they have learned in lectures, text books or from online sources and develop a deeper understanding of them and how they can be applied in future real life situations. Future work will consider a more systematic introduction of authentic learning approaches to produce more objective evidence to support these assertions.

This approach of framing learning in authentic situations is contagious and out ‘bottom up’ approach is gaining traction with many of the academic staff. Many are finding that after an initial input of time they are now experiencing a freeing up of contact hours that were previously spent covering final year advanced courses now find that authentic projects can be used for the student to acquire these skills much more effectively.

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Designing and Using Self-Paced Tutorials: Lessons from the Pilot

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CONTEXT

The literature has shown the importance of students developing threshold concepts and undertaking formative assessment. There are also suggestions within the literature that many students will not undertake beneficial activities that display no direct reward in terms of grades. A new electrical engineering common first year subject with 450 students resulted in bottle necks for providing effective feedback. An online self-paced tutorial resource was created that advanced students through core threshold concepts, supplemented with non-assessed activities that guided students through the process of solving problems and understanding class material

PURPOSE

The purpose of this pilot study was to answer the research question 'Will students use this ungraded resource and how would they use it?' Findings from this study will be used to expand the resource and better target the design, implementation and usefulness.

APPROACH

Self-paced tutorials were designed based on recommendations from the literature. They were placed on the subjects Moodle site and promoted as a free resource, having no direct contribution to grades, that would reinforce threshold concepts. Moodle analytics were used to measure student interaction and progress with the tutorials. A survey was completed at the end of the session to gain additional feedback.

RESULTS

The study found that approximately only a third of students in the subject engaged with the self-paced tutorials. The students that did engage found the resource beneficial, but the feedback suggested that dedicated tutorials on more complex exam styled questions were needed. Insufficient feedback was received from students that found no benefit from the resource. At least 91% of students that failed the subject did not fully engage with the self-paced tutorials.

CONCLUSIONS

The initial student usage from the pilot provided enough encouragement to use the feedback to develop more modules to support student learning. The modules once developed can be reused across numerous years and shared with other campuses. The design structure can be considered by other academics attempting to develop similar resources. The biggest challenge moving forward is trying to encourage the students at most risk of failing to engage with the self-paced tutorials. This may be due to no direct reward in terms of grades.

KEYWORDS

Formative assessment; Self-paced learning; Threshold concepts

Designing and Using Self-Paced Tutorials: Lessons from the Pilot

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Introduction

It is generally well acknowledged that feedback plays an important role in helping students advance their education. Good feedback practice is associated with: clarifying good performance; developing reflection and self-assessment skills; informing students about their learning; increasing motivation and self-esteem; closing the gap between current and desired performance; and providing information to teachers to help shape their teaching (Nicol & Macfarlane-Dick, 2006). There are many forms of feedback both direct and indirect that are being used in the higher education sector. Formative assessment is one form of feedback rising in popularity. The use of formative assessments has been found to allow students to learn from their mistakes leading to an improvement in student performance (Hwang & Chang, 2011; López-Pastor, Pintor, Muros, & Webb, 2013). However, providing good feedback, such as through formative assessments, can lead to workload challenges for the instructor, especially when associated with large class sizes and limited resources (López-Pastor et al., 2013; Poza-Lujan, Calafate, Posadas-Yague, & Cano, 2016).

A new common first year electrical engineering subject (representing ten engineering majors) with approximately 450 students led to the challenging task of providing enough support and feedback to aid learning within resource constraints. The subject was comprised of weekly two-hour lectures, one-hour tutorials and two-hour laboratory sessions. Multiple approaches of support were considered, such as running PASS sessions (Power Ms, 2010). Funding constraints and the desire to provide flexible, any time learning led to the development of several self-paced tutorials that provided students confirmation of the attainment of key threshold concepts. Targeting the resources at threshold concepts was important as it has been found that if students do not reach understanding of the key concepts they can 'get stuck' finding it extremely difficult to move forward in their learning (Meyer & Land, 2006).

The self-paced tutorials were designed as SCROM packages integrated into Moodle that provided alternative instruction to content discussed in lectures and tutorials and provided formative assessment opportunities to help guide students through the process of solving electronics based questions. To allow students autonomy over their learning it was decided that this resource would not be used toward student's grades. However, such ungraded approaches have been found to be mostly ignored by the students that would benefit from them the most (Nikolic, Stirling, & Ros, Online Early Access). Therefore, the purpose of this pilot study was to answer the research question 'Will students use this ungraded resource and how would they use it?' The research question is answered by analysing student usage analytics and through an online survey with the findings to be used to guide the future direction and development of the resource. The findings are of value to academics interested in developing similar resources. This paper will explore the design of the online tutorials and initial student usage.

Design of Self-Paced Tutorials

Moodle is the University of Wollongong's online learning management platform. Built into the platform are many tools that allow for the dissemination of information (for, example links to presentations, videos and websites) and assessment (such as quizzes). Quizzes provide functionality to provide detailed feedback with each assessment attempt. However, the goal of the self-paced tutorials (SPT) was to integrate both instruction and assessment into the one module, in much the same way a live tutorial would be run. Such functionality is provided by Moodle using uploaded SCROM packages.

The SPTs were designed using Adobe Captivate V7 and exported as SCROM packages to be integrated into Moodle. Adobe Captivate provided a user-friendly interface allowing for both instruction as well as assessed activities within small encapsulated modules. Assessment results and usage statistics were available through Moodle, but a key design decision was made that the assessment results would not be formally used within the subject promoting student freedom to learn without the pressure associated with formal grades. This is because previous attempts to provide graded formative assessment using Moodle quizzes led the students to find ways to overcome Moodle; such as opening the question in multiple tabs, finding the correct answer then entering it into the quiz, with the students focussed on gaining marks and not learning from the experience. The common structure of the SPTs was to blend instruction with assessment, stepping the student through the process of solving electronics based questions. A sample structure is shown in Figure 1 highlighting the blending of instruction and assessment. The figure shows how a threshold concept is translated into a problem. The problem is then broken into a set of quiz based steps asking the learner to answer questions in each step of the solution. Each step is followed by immediate feedback. In this way, a small unit of information is communicated at any one time.

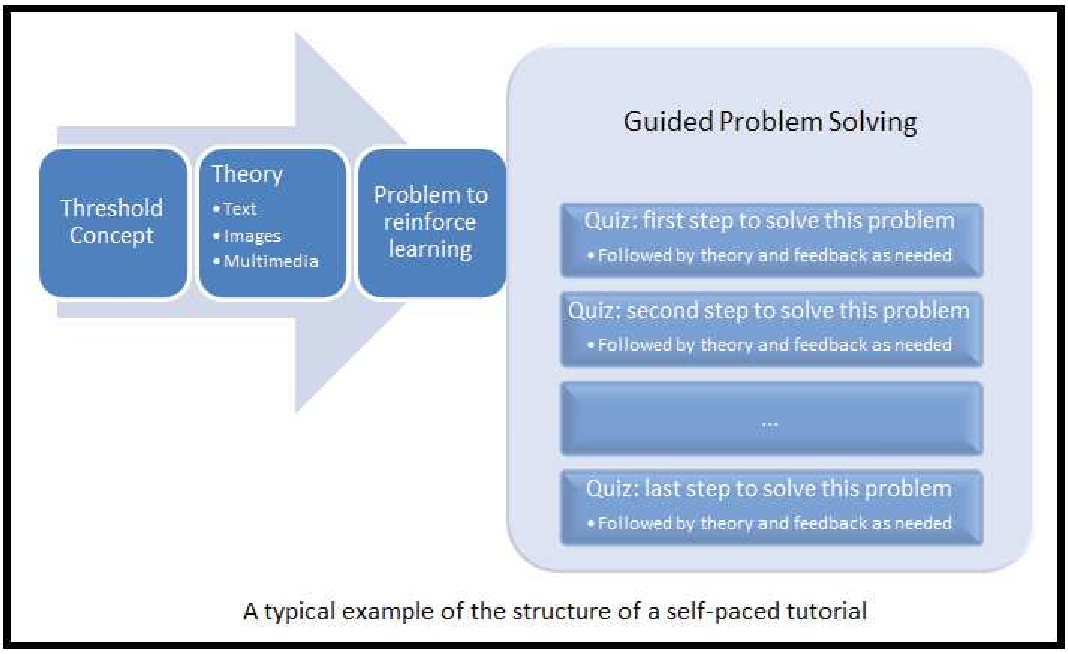

Figure 1: Sample structure of a Self-Paced Tutorial

Figure 2 provides an example of how instruction is provided and then immediately followed with an assessment to check understanding. In this instance students are guided with several slides focussed on developing knowledge of the threshold concept of series circuits, followed by a few activities to check their understanding. Feedback is provided to help the student develop an understanding of where they have gone wrong.

Figure 3 provides an example of how the SPT is used to guide students through the process of undertaking nodal analysis. Nodal analysis is typically found to be challenging by many learners. They require to understand the concept of a node, voltage at a node, current

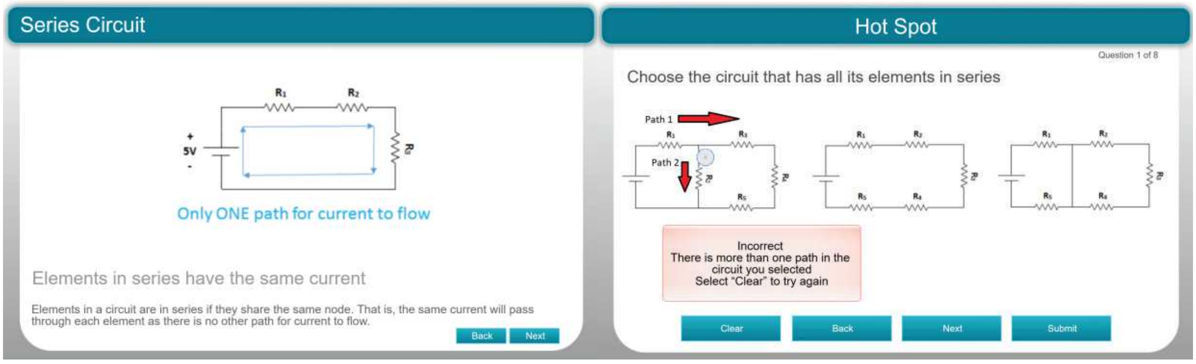

Figure 2: Sample of reinforcing instruction

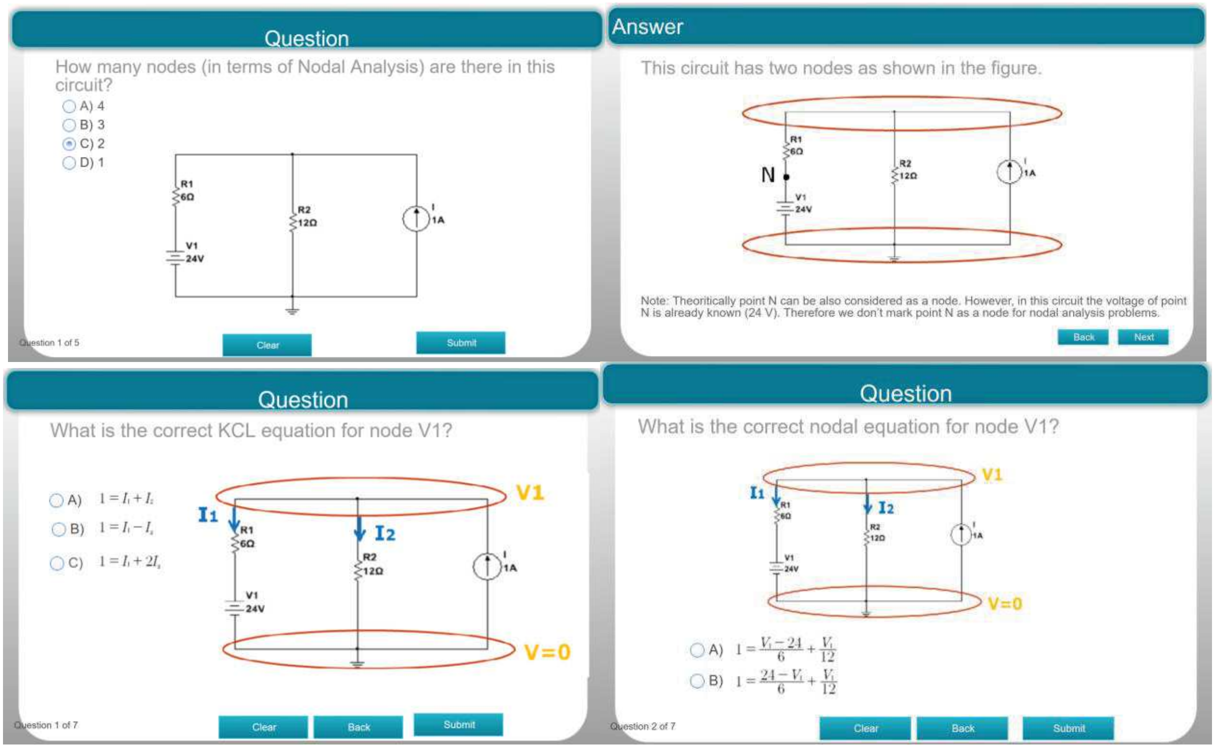

Figure 3: Example of stepping through a problem (selected steps shown)

through a node, Kirchhoff's Current Law (KCL) and solving general simultaneous equations. Learners are stepped through the process of identifying the nodes, determining the KCL equation and then identifying the correct nodal equation. Again, the blending of instruction and assessment is used to provide students with the confidence in overcoming the threshold concept.

Research Method

The pilot study was undertaken in 2016 during the months of July to October (with exams in November and supplementary exams in December) in the subject ENGG104. A total of 448 students were enrolled covering the civil, computer, electrical, environmental, materials, mechanical, mechatronics, mining, telecommunications and flexible (undecided) engineering. A total of ten SPTs were designed for the pilot covering DC circuit basics, series and parallel circuits, solving equations, nodal analysis, capacitors, superposition and Thevenin's theorem. The SPTs were advertised to the students in the lecture and allocated a section within the subjects Moodle site. The SPTs were advertised as a self-help resource that did not count towards their final grade with the onus on students to determine their suitability. The students could retake any module as many times as required and could undertake them at any time. Due to the research nature of the pilot, students were clearly informed that their interaction with the resource would provide consent to the use of Moodle data analytics associated with the SPTs. This may have prevented some students from engaging with the SPTs and may have some impact on the findings presented in this paper. Eight of the modules were available to the students from the start of the teaching session in July. The last two modules became available from the start of September.

Results & Discussion

Engagement with the SPTs peaked with the first module based on introducing series and parallel circuits. At this peak only 61% of students showed any interest in exploring the resource. From the second module engagement dropped to a third of students with engagement dropping steadily thereafter with the average usage across all ten modules being 28% (noting that the last two modules were released with a two month delay possibly contributing to lower the average). It could be assumed that of those that attempted the first module and did not engage with any further modules either did not find the module of value or did not enjoy the experience of using the SPT. There is also another possibility that given time demands from this subject and other subjects, students may have put off attempts until a later date and simply did not get to it. This possibly suggests the importance of ensuring that the first module provides the best possible experience. Table 1 shows the distribution of student attempts across the modules including the percentage of students successfully completing (100% grade) and those not engaging (0% grade) with the module. The data shows that of the students engaging with the modules, many did not try to ensure full understanding by attaining a 100% grade; the more complex the module, the lower the completion rate. That is, they could see that they had not fully grasped understanding of the threshold concept and for some technical or personal reason did not try the module again to benefit their understanding. This is further analysed by looking at the number of attempts made with each module, seen in Table 2.

Table 2 shows that most students engaging with the SPTs either only needed one attempt or more, but did not undertake more attempts to successfully complete the module. This could have been for several reasons including: technical issues; did not find the module of any benefit; skipped ahead and saw the answers through the guided feedback and believed that a reattempt would be of no value; were overloaded with other commitments; or, simply were not motivated.

Table 3 outlines the monthly statistics as to when the students attempted each module. All but the last two modules were released at the start of the teaching session in late July. As expected, the data shows a loose correlation, with most usage centred around the period the topic is covered in the lecturers as well as the week 7 (in early September) in-class test. Usage in November and December indicates usage prior to final and supplementary examinations. Therefore, the data suggests that for those engaging with the SPTs exam preparation played an important role in their usefulness for students.

At the end of the session an anonymous online survey was conducted. A total of 33 students (7.3%) responded to the survey. All students that responded to the survey found the SPTs as useful to their learning experience. Unfortunately, this provides a limitation in that no data could be analysed to develop an understanding as to why other students found no use with SPTs.

Table 1: Engagement with the Self-Paced Tutorials

Self-Paced Tutorial Module	Attempted	Completed Successfully	Accessed with no engagement with assessment
Series and Parallel Circuits	61%	46%	13%
DC Circuit Basics	36%	82%	2%
Kirchhoff's Law Basics	39%	80%	6%
Identifying Nodes for Nodal Analysis	38%	75%	1%
Writing Nodal Analysis Equations	38%	49%	12%
How to Solve Simultaneous Equations	23%	57%	15%
Superposition	29%	51%	16%
Thevenin's Theorem	31%	38%	22%
Capacitors in DC Circuits 01 (released Sept)	18%	27%	17%
Capacitors in DC Circuits 02 (released Sept)	11%	41%	8%

Table 2: Student Attempts at Completing Each Module

Self-Paced Tutorial Module	Completed Successfully	1 Attempt	2 Attempts	3 Attempts	4 Attempts	5+ Attempts	Total Attempts
Series and Parallel Circuits	46%	274	68	19	5	3	369
DC Circuit Basics	82%	161	18	2	0	0	181
Kirchhoff's Law Basics	80%	174	7	1	0	0	182
Identifying Nodes for Nodal Analysis	75%	169	18	3	0	0	190
Writing Nodal Analysis Equations	49%	169	29	9	2	0	209
How to Solve Simultaneous Equations	57%	101	2	0	0	0	103
Superposition	51%	131	14	0	0	0	145
Thevenin's Theorem	38%	138	11	0	0	0	149
Capacitors in DC Circuits 01	27%	82	7	1	0	0	90
Capacitors in DC Circuits 02	41%	51	4	0	0	0	55

Table 3: Student Attempts by Month

Self-Paced Tutorial Module	July	Aug	Sep	Oct	Nov	Dec
Series and Parallel Circuits	190	80	52	22	21	4
DC Circuit Basics	64	44	41	15	15	2
Kirchhoff's Law Basics	34	61	50	17	18	2
Identifying Nodes for Nodal Analysis	28	54	64	17	25	2
Writing Nodal Analysis Equations	21	46	83	23	33	3
How to Solve Simultaneous Equations	12	22	41	10	16	2
Superposition	10	26	68	16	23	2
Thevenin's Theorem	10	29	63	19	25	3
Capacitors in DC Circuits 01	N/A	N/A	23	43	21	3
Capacitors in DC Circuits 02	N/A	N/A	15	28	12	0

The usage data in Table 3 is supported by the survey response data in Table 4 indicating that the SPTs were mainly used after the content was taught in the lecture and particularly before a quiz or exam. Reasons for using the SPTs were based on helping understand the content, quiz or exam preparation and testing knowledge without the worry of assessment marks as seen in Table 5. This suggests that the ungraded nature of the tutorials was a drawcard for the students that engaged with the SPTs. Additionally, 97% of the respondents stated that the pilot should be expanded with more modules.

Table 4: Use of Self-Paced Tutorials

When did you mainly use the Self-Paced Tutorials?	Response
Before the context was taught in the lectures	6%
After the context was taught in the lectures	27%
Before scheduled tutorial session	3%
After scheduled tutorial session	3%
Before a quiz or exam	45%
Other (please specify)	15%

Table 5: Reasons Students used the Self-Paced Tutorials

Why did you use the Self-Paced Tutorials? (select all that apply)	Response
I was curious as to what they were	48%
I needed help understanding the content	70%
I wanted to test my knowledge of the topics without the worry of assessment marks	70%
Exam or quiz preparation	67%
There was no PASS class assigned for this subject	30%
I thought they were compulsory	3%
Other (please specify)	9%

The survey provided students with an opportunity to express positive and negative comments about the design of the SPTs. Most of the comments expressed that the '*design was good'* and the SPTs are *'very helpful'* and '*I like that I am tested on that very information that is presented*'. However, common across most comments was the need for '*more questions or explanations*' and for '*harder questions*'. Some students also commented on the desire to be able to redo various modules, already possible and suggests better communication of information is required. However, as outlined earlier the respondents were those that found the SPTs useful and therefore feedback on how to improve the resource for those that failed to engage is missing.

As Nikolic et al. (Online Early Access) found that students needing to engage with ungraded formative assessment the most actually didn't, it was important to analyse usage for the 56 students that failed the subject. It was found that 73% did not engage at all with the SPTs, 18% only attempted a few of the easiest modules, 5% engaged but in most cases never achieved full marks and 4% only attempted selected modules. Therefore, at least 91% of students that failed the subject did not take full advantage of the SPT resource providing support to the findings of Nikolic et al. (Online Early Access).

Conclusion

This pilot study attempted to answer the research question 'Will students use this ungraded Self-Paced Tutorial resource and how would they use it?'. The research data indicates that only approximately a third of all students were willing to engage and use the resource on an ongoing basis. Of those that failed the subject at least 91% did not fully engage with the SPTs supporting the work of Nikolic et al. (Online Early Access) that a major problem with ungraded formative assessment is that those that need the feedback the most don't engage. Moving forward incentives need to be found to encourage such engagement.

As this was a pilot, the results and feedback provided some encouragement in continuing to develop more modules and refine the existing modules. Once built, the resources can be reused across many years saving cost and can also easily be shared with our other campuses. In the future, it would also be of benefit to compare the participation rate with that of PASS. The authors hypothesize that the participation rates would be similar. It was found that the main way the SPTs were used was for preparation of a quiz or exam, followed as a supporting resource after the lecture.

Common in the feedback was the need for more and harder questions. As a result, the next iteration will contain two different modules for every threshold concept. The first will be labelled as 'basic' targeted at understanding the fundamentals of the concept. The second will be labelled as 'advanced' targeted at working through examination level questions. Unfortunately, no feedback was provided by students that found no benefit from the SPTs providing it difficult to enhance the modules to better engage these students. The authors will try and undertake a focus group to gather this understanding.

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TRIZ – trans-disciplinary innovative methodology

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SESSION S2: Educating the Edisons of the 21st Century

CONTEXT

Tremendous rise of knowledge in all spheres of human activity has led the need to find answers on eternal question about education content (subject, "what to teach") and form of education (manner, form, "how to teach"). The curricula content is being by broad variety of specialisations. The form of education is aimed at securing an extensive knowledge base for students to acquire subject knowledge (to know ´what´). Much less accent is put on the development of student´s habits and soft skills to learn methods (to know ´how´). The effort to develop a systematic approach to the technical problem solving and creativity potentials (to learn "how better" or "how else") receives little attention. The last two issues, a systematic approach and creativity are not cultivated enough throughout the educational process and in companies. On the other hand, analytic and synthetic methodology is available derived from the patent state of the art called Teoriya Resheniya Izobretatelskikh Zadach - TRIZ. It is the Russian title and acronym for the "Theory of Inventive Problem Solving". The methodology can go with users, step-by-step, through systematic object analysis up to creative conceptual solutions.

PURPOSE

The purpose is to illustrate the innovative potential of the TRIZ methodology for engineering education and for innovative projects solved in companies. The aim is to summarise the experience of implementation of TRIZ in Czech Republic and Slovakia obtained during the last 20 years.

APPROACH

The TRIZ methodology is explained shortly, then benchmark and two successful practical applications in practice are presented. And in the third part of the paper the experience of TRIZ implementation is summarised. The benefits of TRIZ methodology are illustrated on the basis of evaluated answers given by the students and mainly specialists from R&D departments. The question why TRIZ as an analytic and synthetic methodology is not implemented to a greater extent remains unanswered.

RESULTS

The potential of TRIZ to improve attractiveness of engineering studies and to increase self-confidence sot those coming up with real innovations is unique. Nevertheless, mastering of the relatively complex and sophisticated TRIZ is not easy. That is why experienced lectures able to motivate students are needed as well as coaches for implementation in companies.

CONCLUSIONS

The TRIZ methodology can be studied and mastered. TRIZ can bring qualitative change in teaching and learning and increasing the ability of users to solve technical problems systematically and creatively. A systematic approach together with creativity is combination of skills required in today´s engineering education and in tomorrow´s innovative practice.

KEYWORDS

TRIZ, education, engineering, innovation.

What is TRIZ

The life cycle of a technical object is always accompanied by problem solving through all phases. First of all, the problems have to be analysed to identify the crucial ones correctly. Then derived inventive tasks can be formulated and tackled effectively.

TRIZ is the methodology developed since 1946 by G. A. Altshuller (1956, 1989). It is still being developed and applied in many countries by his followers. TRIZ respects a systematic approach to the object to be innovated and, consequently, enhance of its users.

Of course, TRIZ does not replace the designer's thinking, but methodically and significantly improves concentration and focus of solvers on step-by-step analysis of the object to formulate problems relevant to the target of the innovation project. Then it offers the generic (heuristic) recommendations for dealing with typical inventive tasks transformed from innovative problems. Whether the user interconnects abstract recommendations with specific conditions of the problem solved in his mind and intensifies his knowledge in this way - depends on his/her mental ability.

The methodology of TRIZ consists of two complementary methods.
The first method is advanced VEA – Value Engineering Analysis of the object (design or process). It is a systematic support of users which helps to find the answers to the questions "what and why" in the object has to be improved. The result of the object analysis is a list of formulated problems to be solved.
The second method is the heuristic Algorithm of Invention Problem Solving. It is translation of the Algorithm Reshenia Izobretatelskikh Zadach – ARIZ of Russian origin. It is a working procedure of the algorithmic type, a chain of the thinking ´tools´ for seeking idea of solutions, the tactics of users, the algorithm which assists in seeking the answers to the questions of ´how´ an innovation problem, resulting from previous VEA, could and should be solved.
Those interested in more information and TRIZ study will find many available publications and offers on the web portals.

How TRIZ helps a solver

The user of TRIZ in team cooperation initially analyses the object and its inherent problems. Then, within the frame of mentioned algorithm, innovative problems have to be transformed into inventive tasks in several typical forms which are: Technical Contradiction - TC; or Physical Contradiction - PC; or Model of Conflict of two interacting substances – MC; or Problematic Technical Function - TF; eventually unsatisfactory ´state´ of some component. After that the specified TC can be overcome by the recommended Inventive Principles - IP. The detected PC can be resolved by means of relevant Separation Principles - SP. The model of substance-field conflict - MC can be solved by several transformation Models of Solutions - MS. Problematic TF can be improved or principally changed by the recommended Effects from natural sciences - EF. Future ´state´ of the object can be predicted by ´consultation´ with more Trends of Engineering System Evolution - TESE. All the mentioned abstract recommendations offered within the frame of ARIZ can be understood as being heuristic, inspiring various inventive ideas to tackle inventive tasks identified inside the innovative problems (Devoyno, 1996; Salamatov, 1996; Souchkov, 2010).

Some of these inventive tasks and recommended heuristics will be shortly demonstrated in the following educational example and then in two examples of a real innovations.

A problem, derived tasks and heuristics recommended for its solutions

A clarifying benchmark will be used now to explain the four typical formulations of inventive tasks (TC, PC, MC, ´state´ of the object) and relevant heuristics mentioned above.

As a case the following problem will be considered: "How to improve the stability of the yacht intended for sailing under the conditions of strong side wind"? It is known already that the problem should be reformulated into the form of several typical inventive tasks.

Technical contradiction (TC) and Inventive Principles (IP) to overcome it

TC is specified in the problem when the usual manner to improve one characteristic or parameter leads to the worsening of another characteristic or parameter (Figure 1). For example: when the width of the hull is increased to improve stability (positive effect, **+**), the speed of the yacht decreases (negative effect, it is **-**). The one generalised inventive principle (IP, heuristic) relevant to dealing with this specific TC is: ´Segmentation´.

Physical contradiction (PC) and Separation Principles (SP) for its solution

A deeper analysis of TC (according to several steps in ARIZ or built-up Root Cause Analysis – RCA diagram) leads to the physical contradiction PC as the cause of TC.
An extremely important feature of PC formulation is that it indicates only one component and dictates contradicting values for one specific parameter of the component. In case of the yacht there is one possible formulation of PC: The hull´s (component) width (parameter) has to be increased (value of parameter) to achieve stability (**+**) and the hull has to be narrower (opposite value) to retain (do not lose) speed (**+**). For engineers unfamiliar with TRIZ and ARIZ the formulation of innovation task in the form of PC is hardly acceptable. But it is important and good to know that PC is a dialectical formulation and the best possible formulation of the cause of TC as well as the problem to be solved. That is why the paradoxical formulation of PC shifts solver´s thinking to the "aha effect", to the moment of finding an idea solution. One of the relevant separation principles offered (SP, heuristic) to solve the PC is: ´Separate in space´. (Devoyno, 1996; Souchkov, 2010)

Model of Conflict of substances (MC) and Model Standards (MS) for its solution

Perceived as a model conflict of two substances – MC can be the conflict (in this case insufficient interaction) between the hull and water because the hull in water can be easily inclined under action of strong side wind. The so called ´Su-Field´ analysis - another part of ARIZ - offers several model solutions - MS for such MC. Particularly for MC – insufficient hull interaction with water - ´Segmentation in space´ is recommended again (Belski, 2007).

Recognised ´state´ of the object and offered inspiration from trends

An analysis of the object gives good information concerning the state of each component, including the working ´tool´. One of the several trends of engineering systems evolution - TESE states: "Working tools of technical systems develop in a trend of rising segmentation". The working tool of the yacht is the hull delivering shipload principle to the yacht. A standard hull is a monolith. According to the ´trend´ mentioned, the hull should be divided.

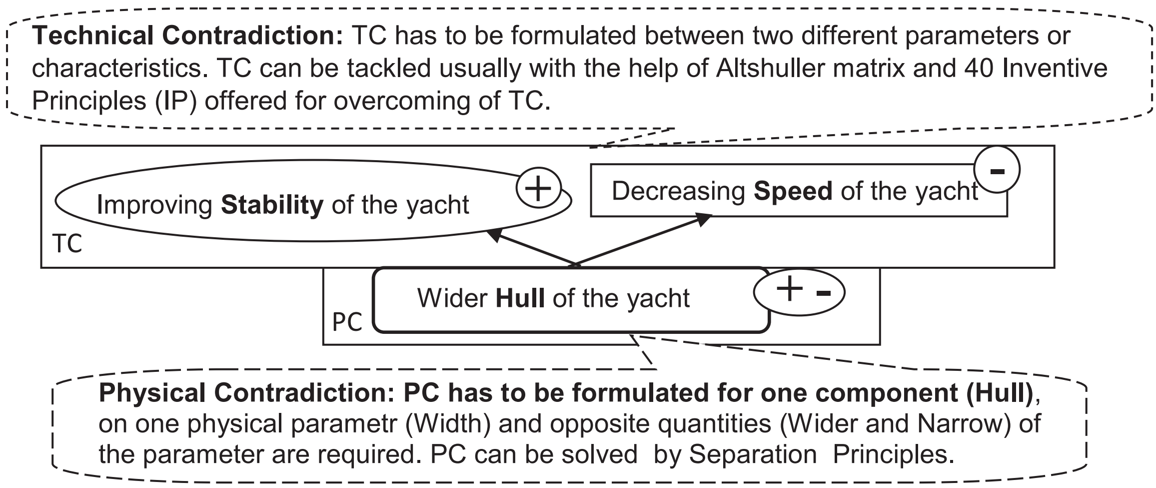

Figure 1: Positive (stability) and negative (speed) effects in TC and PC (wider hull) as a cause

Now, after this extremely short demonstration of only four solving instruments (IP, SP, MS and TESE) a provocative question is relevant. How far or near is the problem solver from the ´aha effect´, from the moment of finding an idea solution? Well, the solver obtained four heuristics, abstract but more or less relevant recommendations how to arrive at ´win – win´

solution. The solver should think about ´segmentation´ evoked several times. How to transform these heuristics into an idea and conceptual solution? How to improve parameter stability AND retain the speed of the yacht in this case? Psychologically inert men remain ´far away´ and intact, while an ingenious engineer should be inspired enough. It depends on the solver´s abstract thinking ability. It is known that an engineer should be able to combine abstract and specific thinking. "If you think you are an engineer – think" (TRIZ folklore).

Product and process Innovations with TRIZ – case studies

Two case studies will be presented as cases of successful application of TRIZ. But it is not easy and effective to describe application of the analytical and synthetic part of the TRIZ methodology and innovations achieved, because the paper format is limited. Only short description of problems, solving ´instruments´ used, figures (Figure 2, 3 and 4) and summarisation of results in tables (Tables 1 and 2) comparing the states before and after innovations follows in this section.

The first case presents an innovation of an active hinge of car bonnet, which was innovated to improve security of pedestrians in collision with cars namely at pedestrian crossing in towns where the most severe accidents are occurred (Figure 2). Fast and controlled lifting of the bonnet by motion of an active hinge, can extend deformation zone, absorb impact energy and mitigate the consequences of collision between pedestrian´s head and rear end of front car bonnet.

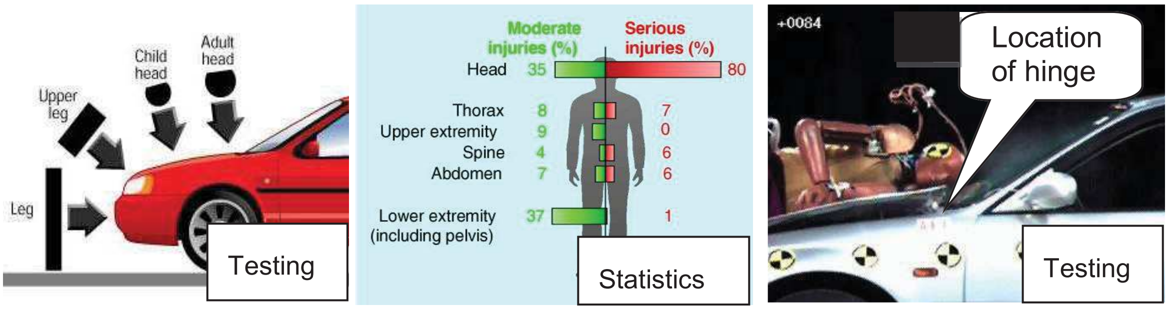

Figure 2: Statistics indicate the percentage and severity of head injuries (Euro-NCAP, 2012)

Which parts of TRIZ methodology have been used? At first it was analysis of the existing complicated and slow active hinge of the bonnet. Then some parts of ARIZ were applied. It means formulation of TC and partial inspiration from IPs, formulation of PC and inspiration from SPs, trimming components and merging of two alternative systems (Figure 3), key technical function and inspiration from "ball lock" effect for design of a new actuator were considered.

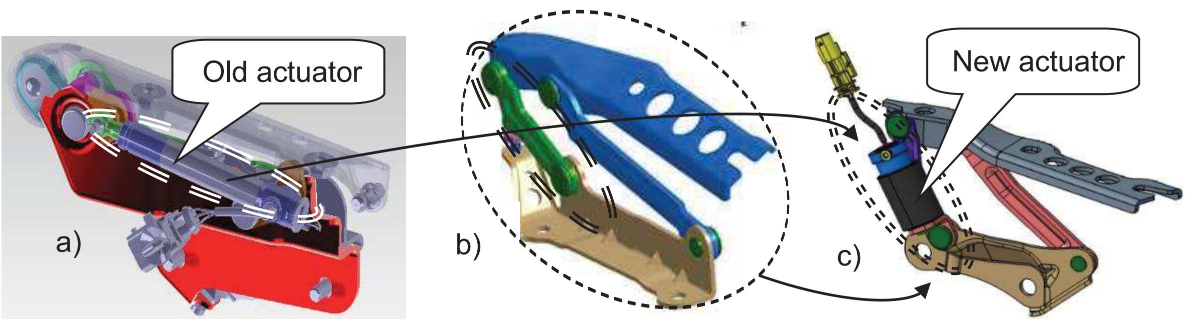

Figure 3: Old complicated and slow active hinge of front car bonnet (a), old passive hinge (b) and new simple and quick active hinge with new actuator (c)

The new active hinge of the bonnet design with a new actuator meets technical and legal requirements and has several important benefits (Table 1).

Table 1: Comparison of the old and the new active hinges of car bonnet

Comparison criteria	Old active hinge	New active hinge
Number of parts of the old and new active hinges	100%	48%
Uniformity of parts (passive hinge / active hinges)	20%	75%
Production cost	100%	60%
Time necessary for relaxation	4-6 ms	Lower than 1 ms
Pyrotechnic element: cost of replacement	100%	55%

The second case presents an innovation process, in particular improving effectiveness of ceramic cores production in pressing process.

Casting systems often include ceramic cores produced by pressing. The specific pressure on the pressed mass during pressing process is relatively high, and therefore negative effect occurs - "sticking" of the pressed mass to the surface of the mandrel. To reduce this negative effect, the ceramic core cannot be pressed on one stroke of the mandrel but has to be shaped in 4 cycles including 13 sequential operations (Figure 4). Value of the original pressing process is low.

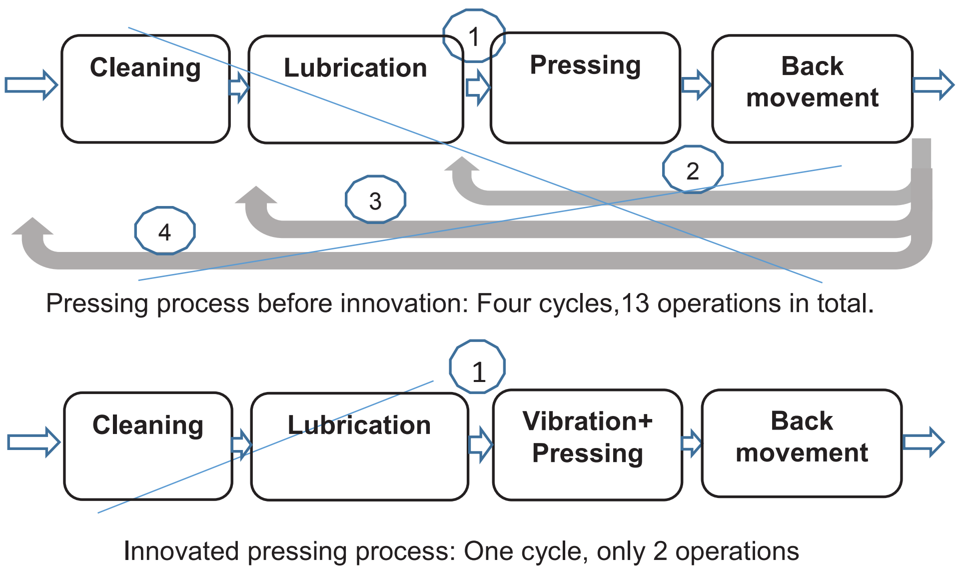

Figure 4: Comparison of original and innovated pressing of ceramic cores for casting

To increase the productivity of the pressing process of quality ceramic cores, some parts of TRIZ methodology have been used. At first, Root Cause Analysis – RCA diagram has been performed (Souchkov, 2010) to identify and visualise contradictions resulting in the negative effect of „sticking“. Then a good new solution of contradictions has been found with the help of inventive principles and separations.

Table 2: Comparison of original and innovated pressing of ceramic cores for casting

Pressing process	Number of mandrel movements	Number of operations	Production time [s]	Productivity [cores/7hours]
Original, 4 cycles pressing	8	13	25	810
Innovated, 1 cycle pressing	2	**2**	12	1550

Experience from implementation

TRIZ methodology has been popularised in the Czech Republic in technical journals sporadically since 1980. Since 1993 several original publications from Russian or English have been translated into Czech (Altshuller, Devoyno, Belski, Salamatov, Ivanov, Souchkov, Guin, etc.). Since 1996 TRIZ has been taught on a regular basis at Brno and some parts of TRIZ have been implemented in Prague, Liberec, Pilsen, Ostrava, Zilina and Kosice universities.

TRIZ has been an optional course for Master students of two departments of the Faculty of Electrical Engineering and Communication (FEEC) at Brno University of Technology (BUT) since 1996. As a rule, there have been 15 to 30 students or up to 55 in some years. Last year the course of TRIZ was launched as an optional course also for eleven PhD students from FEEC. Starting from this academic year the course is optional for Master students of all departments of FEEC. Moreover, within the frame of project Modern and Opened Study of Technics - MOST the course TRIZ is offered as a ´trans-disciplinary´ optional and faculty independent course for all students of all faculties of BUT Brno from this academic year.

Over the long period of TRIZ implementation in education and practice in the Czech Republic the methodology has received favourable responses which is the result of the popularization activity of several teachers and consultants organized in ´TRIZing´ Czech Association, member of MATRIZ International Association.

Content of TRIZ optional course at BUT Brno

A short content of TRIZ course for Master and PhD students at FEEC and BUT Brno:
1. PM: Basic terms of Project Management (Aim and purpose of innovative project, SWOT, outputs, activity, resources, people, technology, time, space, money, Log Frame description).

2. TRIZ as an innovative methodology:
- VEA: Analysis of the object (system modelling, components, structure, functions, parameters, costs, evaluation of components), RCA diagram, trimming, additional functions, list of problems to be solved. Analyses of many case studies are presented.
- ARIZ: Transformation of problems into inventive tasks and search of idea solutions (technical contradiction and inventive principles, physical contradiction and separation principles, model of substances in conflict and models of standard solutions, problematic technical function and effects known from natural sciences, state of the object and possible inspiration from evolution of engineering systems). Synthesis of many cases are presented.

3. Application of TRIZ within the frame of a ´micro-project´. Students elaborate approximately 20 pages describing the analysis and synthesis of the selected object to demonstrate ability to apply the VEA analytical steps and synthetic solving instruments from ARIZ to find realistic idea how the object could be improved. To be efficient, TRIZ education requires individual work.

Students on the course (26 hours of lectures, 26 hours of training, case studies, work with software support) are evaluated through 3 tests (PM, VEA, ARIZ), a micro-project (20 points) and written and oral examination at the end of semester (60 points).

TRIZ for companies

The second part of the course is offered as a three-day educational course to the companies. TRIZ is attractive namely for companies with an active R&D department. The most effective way of introducing TRIZ to the companies is the direct communication with the head of the department. This person, usually of technical qualification, has to innovate products and that is why he/she is able to recognize possible TRIZ impact on innovation processes. It is mostly ineffective to offer TRIZ through HR department.

Authors come to companies to give three-hour motivation lectures. As a rule, a short-term 2+1 day educational course follows. It is our good practice proven over the past ten years.

Anyway, the educational course can be followed with repeated practical TRIZ applications only in the companies where an adjusted combination of several internal factors is present. Especially staff and management qualifications and motivation are key factors for acceptance and implementation. Then TRIZ as a non-trivial methodology can ´resonate´ with other advanced factors creating the ´innovative culture´ inside a company.

Important for education at universities and the future of the TRIZ methodology is the fact that the vast majority of TRIZ touched engineers recommend studying and mastering the methodology during university studies (Figure 5, question and answers 5).

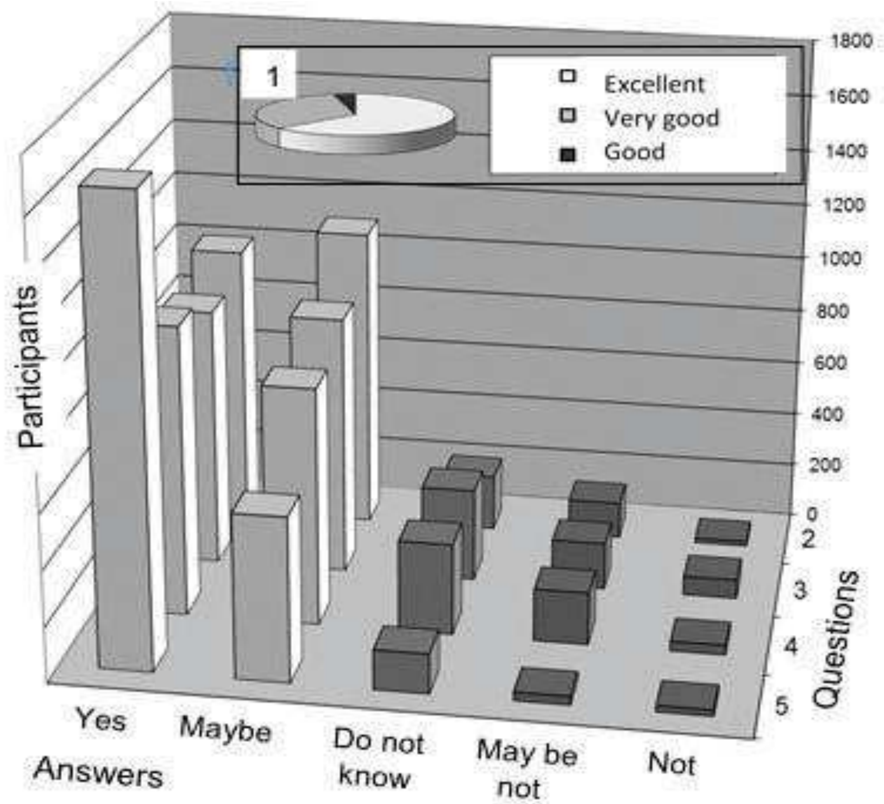

Figure 5: Answers of 2500 participants after motivation lectures or 2+1 day courses of 2 - 20 hours. Results from companies / universities (90/10) as of September 10, 2017

Questions asked:

1. How do you understand the content and form of the TRIZ methodology?
2. How do you evaluate applicability of TRIZ and software support in your company / school?
3. Would you be interested in occasional consultation of your innovative tasks?
4. Would you be interested in studying and mastering TRIZ methodology?
5. Would you recommend TRIZ to your son / daughter, or school and university students for studying and mastering?

Experience from answers: The more time spent with TRIZ, the more positive the references were. But no matter how many positive references there are from more than 2500 listeners, mostly from companies, the methodology has not become a common issue either at universities or in corporate development departments yet (Bušov; 2002 - 2016).

Mastering the non-trivial TRIZ methodology (if compared with some others ´methods´) requires serious study, educational examples and time for real applications. That is nothing new; reality always puts obstacles in the way to obtaining all values. Only valueless thing can be obtained easily and immediately. The same applies to good education and good schools. Knowing that there is no cheap and so called ´caesarean´ way into TRIZ, authors will stimulate further effort, with others educators and engineers, how to implement TRIZ into education and innovative practice more effectively.

Conclusion

There's no doubt that engineering graduates provided with the methodology of systematic and creative thinking would adapt more easily and rapidly to the variable demands of the dynamic reality in practice. The paper presented TRIZ as a challenge, as relatively universal because trans-disciplinary methodology, as well as elaborated and instrumental, analytic - synthetic methodology, which guides the solvers through a comprehensive analysis of the problem object to the formulation of various innovative problems and then to the formulation of typical inventive tasks to be solved. Then TRIZ offers appropriate recommendations (heuristics) on seeking ideas and solving concepts for implementation.

TRIZ is the empirically derived, systematic, relatively complex methodology understandable for students as well as for teachers who wish to make the educational process more attractive for all participants. The same applies to engineers - solvers of technical innovative problems in practice - who wish to deal with innovative projects more effectively.

The methodology can be studied and mastered. It supports both the system approach and creativity needed for inventive solving process. It is a challenge for teaching and learning, for developing the ability of users to solve not only but namely technical problems systematically and creatively. These ´ingredients´ are needed for most human activities, particularly for engineering education and innovative practice in companies. A systematic approach together with creativity is necessary in today´s engineering education as well as in today´s and tomorrow´s innovative practice. TRIZ is a challenge for ambitious teachers.

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Making sense of Learning Management System's quiz analytics in understanding students' learning difficulties

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CONTEXT

In engineering and other tertiary education programs, it is generally held that formative assessment can be a strong driver of active participation and learning. Two years ago we added a new assessment component in our algorithms subject, namely mandatory weekly quizzes. The aim was to encourage students to stay abreast with lectures and tutorials, and to identify common misconceptions in a subject that deals with numerous difficult algorithmic concepts. It was hoped that the quizzes would expose and challenge student misconceptions, and more generally support the mastery of important algorithmic tools and techniques. The quizzes are hosted within our institution's Learning Management System (LMS) which also provides learning analytics tools, including metrics for student engagement and performance.

PURPOSE

After rolling out the student quizzes we turned to evaluation. Apart from measuring the extent of student engagement, we were interested in the (initially vaguely defined) "learning value" of individual quiz questions. Through the LMS metrics, we wished to evaluate the quizzes' influence on student engagement with subject materials, and to discover which questions best expose common misconceptions harboured by students.

APPROACH

We have adopted an action research approach. LMS statistics were gathered and analysed in three successive semesters. For each weekly quiz, the data collected included students' participation statistics, records of multiple attempts made by every student, and LMS measures of question discrimination and difficulty. These data were analysed across the three iterations.

RESULTS

There were marked differences between the LMS statistics of the pilot and two following semesters. Unsurprisingly, student participation grew when quizzes were made mandatory. More significantly, the LMS inbuilt measures of question difficulty and discrimination were found to be extremely susceptible to the number of allowed quiz attempts allowed. We have found them relatively unreliable and unhelpful in identifying useful questions that challenge student misconceptions and we have had to find alternative metrics.

CONCLUSIONS

Feedback from our students strongly suggests that mandatory weekly quizzes do promote student engagement with learning materials. However, in our attempts to gauge question quality, we find that the LMS metrics for question analysis do not support a "learning value" assessment. They are so strongly influenced by the number of possible quiz attempts that they are of little practical use. This study therefore illustrates that using the LMS metrics may not be sufficient or straightforward to assess the effectiveness of quizzes on student learning outcomes. Further analytics and investigations will need to be conducted for a deeper understanding for best exposing common misconceptions harboured by students.

KEYWORDS

Quiz questions, LMS metrics, formative assessment

Introduction

Active learning is increasingly promoted within higher education institutions to support students in linking knowledge to meaning and the development of higher order thinking skills. Active learning involves: students engaged in more than listening; less emphasis being placed on transmitting information and more on developing students' skills; higher order thinking and engagement (Bonwell and Eison, 1991). However, encouraging active learning can be a challenge for both educators and students, particularly in large, lecture-based classes (Klein, 2003, Buckley et al. 2004). Much has been written about the use of assessment, particularly formative assessment, to drive active learning in higher education programs (Boud, 2010; Gibbs, 2010; Boud and Falchikov, 2007; Falchikov, 2005; Huba and Freed, 2000).

Formative assessment comes in many different shapes, encompassing a variety of practices, including self-assessments and peer-assessments; Black and Williams (1998) review no less than 250 articles on the topic. Often characterized by its informal techniques and mechanisms to encourage student participation, it is not a pre-condition that formative assessment be tied to summative assessments, although this is often the case (Dunn and Mulvenon, 2009). Gibbs and Simpson (2004) suggest that formative assessments in the form of frequent assignments or tests to distribute student effort across the duration of the semester, often on a weekly basis, promote students' participation and enhance learning. More specifically, several studies have shown that there is a high level of student engagement with regular quizzes; many report upon their positive role in encouraging, for example, the completion of prescribed reading in various programs (Scheyvens et al., 2008; Bonwell and Eison, 1991; Hanson and Moser 2003).

In the computing disciplines, many students struggle with complex algorithmic concepts. To promote students' engagement with teaching materials and engender understanding of important computational methods and theories, we designed a set of weekly quizzes. Each quiz comprised a variety of questions; some were crafted as revision materials, others were set to probe students' learning and challenge their perceptions and interpretations. Students could attempt each quiz multiple times and receive information about which questions they had answered correctly, including some hints for questions they had answered incorrectly. Their reflections on this formative feedback were expected to influence their follow up attempts.

Here we report on our efforts to evaluate the introduction of these quizzes and our attempts to gauge the usefulness of individual quiz questions in challenging common misconceptions and in helping students learn content and concepts.

Context and purpose

The introduction of quizzes, as a formative assessment component, took place within a graduate subject on Algorithms and Complexity. The aim of the subject is to develop student familiarity and competence in assessing and designing software for computational efficiency. Historically, many students struggle with the concepts and topics of this subject. Introduction of quizzes was a mechanism to offer more opportunity for students to be engaged with the subject content and, importantly, to challenge developing mental models of computational processes. Eleven quizzes were devised and set up; one for each week starting in the second week of a 12-week semester. On-line quizzes have been found to be an effective mechanism for incentivizing student completion of work and are relatively time efficient from the perspective of the educator (Wolt and Mason, 2003). As most virtual learning environments provide quiz frameworks for local customization, we hosted these weekly quizzes using the Learning Management System (LMS) of our institution. The LMS offers analytics tools to track student engagement with the quizzes along with some automated tools for question analyses.

Our plan was to use these LMS data to gauge the effectiveness of the quizzes in engaging students with teaching materials and, for individual questions, to assess "learning value", including a question's ability to pinpoint misconceptions. To this end, an action research approach was to be adopted. In the first instance, the quizzes would be piloted; then adjustments to delivery would be made over the course of two subsequent iterations, whilst maintaining the same pool of questions over this investigation.

We note that the quizzes complement lectures, tutorials, and other continuous-assessment components in the subject. In particular, two written assignments challenge students to find good algorithmic solutions to relatively difficult problems. The main aim of the quiz component has been to encourage students to stay abreast during semester, and while individual questions are designed to identify misunderstandings, they are not intended to be difficult.

Approach

LMS data were collected and investigated for every quiz across the three semester iterations of their use. Two separate sets of LMS data were of interest. Firstly, LMS reports of students' participation activities were used as a measure engagement with the quizzes. Secondly, through the LMS metrics of discrimination and difficulty, we hoped to identify the most useful quiz questions for best exposing common misconceptions harboured by students.

Results and evaluation

Conveniently, the LMS allows teaching staff access to student participation statistics for the entire cohort. When a student logs in to access a weekly quiz in Algorithms and Complexity, an attempt is recorded, regardless of whether the attempt is complete or not. For each attempt, the LMS records whether each question is answered correctly or otherwise, and assigns a nominal score as decided by the teaching staff.

As a pilot, the weekly quizzes were trialled in semester 2, 2015 and students were permitted to make up to three separate attempts per quiz. Participation was voluntary, in that there was 'no' mark attached to quiz participation or to the number of answers correct in each quiz. Throughout the semester, teaching staff actively promoted the benefits of ongoing quiz involvement to their students. Of 151 students who completed the subject in the pilot semester, 121 students made a quiz attempt in week 2. Participation statistics are given in Table 1, where a decline is observed over the pilot semester culminating in 66 students attempting the final week 12 quiz, even though this quiz was timed nearest to the examination sitting.

The role of the pilot semester was to fine-tune the delivery of the quizzes before they would become mandatory. The quiz questions were unchanged throughout, but we needed to decide on the best parameters for delivery, including scrambling of questions, windows-of-access, and number of attempts allowed. As pointed out by Gibbs and Simpson (2004), the relationship between marks and effort is not straightforward for students, and as little as 5% of student time may be allocated un-assessed tasks. If too few marks (in this case, 0 marks) are allocated to preparatory work, many students may make the strategic decision to forego those marks and instead focus their time on other pieces of assessment. Thus, care is needed in the design of incentive mechanisms to ensure students balance extrinsic rewards or sanctions with intrinsic motivations to maximize their outcomes.

In the following two iterations, the quizzes were simply a hurdle requirement for the subject. More precisely, a student must successfully complete at least 8 of the 11 online quizzes to be eligible to sit the final examination. No mark was attached to quiz participation or to the number of answers correct in each quiz for these following two semester iterations.

Since the quizzes are intended as learning support rather than gate-keeping, we decided that "successful completion" would mean "getting each of the (3-5) quiz questions right in a single attempt", but also that an unbounded number of quiz attempts would be allowed, as long as the student met the weekly deadline. The questions are mixtures of multiple-choice, multiple-answer, matching, and numeric answer questions, so in general a large number of attempts are needed if a student decides to search exhaustively for the right combination of answers. In one instance, as student had 49 attempts at one quiz!

Table 1 shows how participation rates improved in these semesters, compared to the pilot; for the commencement quiz in week 2,186 students participated in semester 1, 2016 and 175 students in semester 2. Notably, over both semesters, there are only slight declines with week 11 quiz participation recorded as 155 and 126 (semester 1 and 2). This improvement in participation is attributed primarily to the introduction of the hurdle requirement for quizzes, where eligibility to attempt the final assessment was tied to completed quiz attempts.

Table 1: Summary of student participation statistics with weekly quizzes over three iterations

Week	Pilot Semester 2, 2015	Semester 1, 2016	Semester 2, 2016
2	121	186	175
3	109	188	175
4	103	187	170
5	90	179	169
6	72	171	168
7	77	166	164
8	69	163	158
9	63	182	157
10	72	176	148
11	69	155	126
12	66	not delivered	127

LMS Analytics

For each quiz, the LMS's "Item Analysis" tool reports overall attempt statistics for that quiz and its component questions, by relating each cohort's performance on each question compared to their overall performances on the quiz hosting that question. The tool uses two metrics to assess each question: discrimination and difficulty. The following descriptions of each are verbatim from the LMS User Guide: *Discrimination* indicates how well a question differentiates between students who know the subject matter and those who do not. A question is a good discriminator when students who answer the question correctly also do well on the test. Discrimination scores range between -1 and +1. Any question that gets a discrimination score above +0.3 is considered Good. Good and Fair questions may be used to help determine student knowledge levels. Discrimination cannot be calculated for questions where everyone receives the same score (everyone gets a question right or wrong). *Difficulty* shows the percentage of students who answered the question correctly. If >80% of students get a question right it is listed as easy; if <30% of students get a question right it is listed as 'hard'.

The discrimination measure categorizes questions as being 'good', 'fair' or 'poor' and the difficulty measure classifies questions as being 'easy', 'medium' or 'hard'. 'Difficulty' as defined by the LMS does not relate to any learning taxonomies, such as Bloom's, SOLO or Neo-Piaget that have been used to categorize questions as to the degree of learning difficulty as described in the computing education literature (Gluga, Kay and Lister et al., 2013; Jimoyiannis, 2011).

Our main interest was in finding quiz questions that best exposed student misconceptions. We expected that the difficulty statistic reported by the LMS would hint at questions that students found most problematic and could lead to misconceptions.

Pilot

During the pilot in semester 2, 2015, Item Analysis Reports were run for each quiz. Figure 1 shows an example, the Week 10 Quiz Report. The Test Summary shows that: (1) 72 student attempts across four questions; (2) All four questions are 'good' for their discrimination scores, each being above +0.3; (3) Two easy difficulty questions where >80% of the students scored it correct; and (4) Two ‘medium’ difficulty questions where >= 30% and <=80% of the cohort scored the questions correct.

The second section of a Weekly Item Analysis Report lists all questions, each with their description, question type, number of graded attempts, together with discrimination, difficulty, average score, standard deviation and standard error statistics. In addition, the reports visually indicate possible issues with individual questions using a set of symbols beside the question description. The legend for these question classification symbols is shown in Figure 2. In Figure 1, the yellow triangle symbol indicating that the question may have changed since quiz deployment is found beside all questions, and the ‘Linear probing’ and ‘Coin-row instance’ questions are indicated with a red dot signifying LMS recommendations for these questions to be reviewed, most likely for their high difficulty score, that is, ‘easy’ classification.

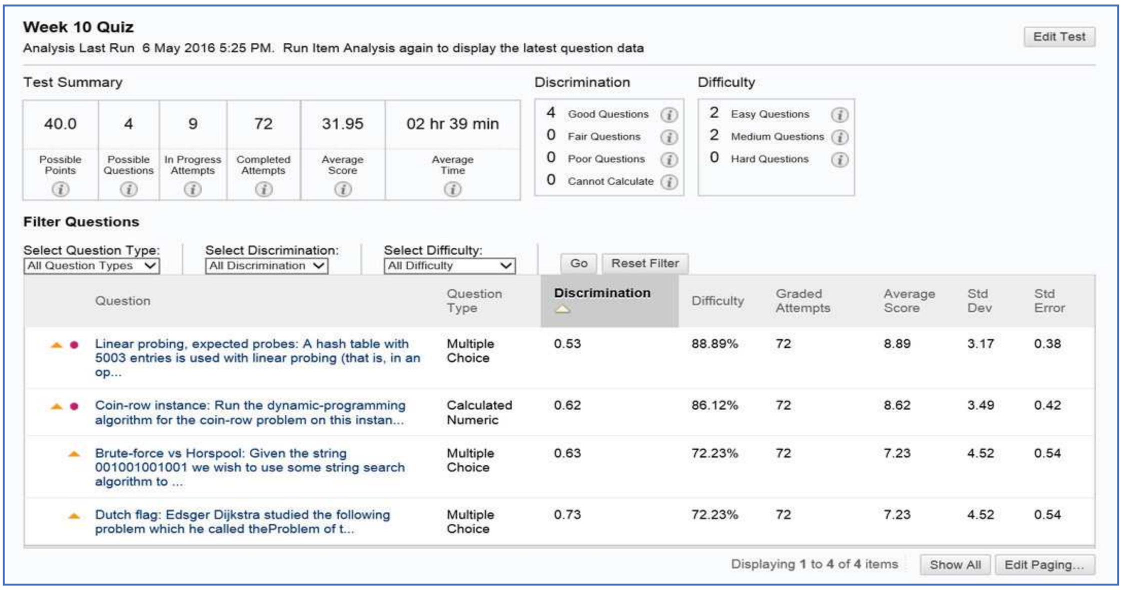

Figure 1: Summary statistics of week 10 Quiz in COMP90038 Algorithms and Complexity, semester 2, 2015 as reported in the pilot Item Analysis Reports

Figure 2: Legend used to classify questions in the Weekly Item Analysis Reports

For an overview of the quizzes and their questions, a collation of the Weekly Item Analysis Reports for the pilot semester is presented in Table 2. The Table lists the number of questions in each quiz, the discrimination classifications and difficulty classification of the quiz questions. In summary, it shows that: (1) All quiz questions have been classified as ‘good’ as their discrimination scores are above +0.3, indicating that students who answered the questions correctly also did well in their respective quiz; (2) All questions have been classified as ‘easy’ or ‘medium’ difficulty, where ‘easy’ questions saw over 80% of the students answered the questions correctly whereas for ‘medium’ difficulty questions, between 30% and 80% cohort answered correctly; and (3) Except for week 8, each LMS Item Analysis report tagged one or more questions as recommended for review; the tool advising that these questions should be more closely examined to assess their suitability in future iterations of the quizzes. Closer examination of how the LMS Analysis tool classifies difficulty shows that the questions ‘Recommended for Review’ are those classified as ‘easy’ in difficulty. These questions are shaded in Table 2.

Table 2: Summary statistics of the weekly Item analysis report for the pilot during semester 2, 2015. Shaded questions are those identified by the LMS as recommended for review.

Quiz	Questions					
	No.	Discrimination	Difficulty			All quiz questions with those 'Recommended for Review' shaded
			Easy	Medium	Hard	
2	5	5 Good	1	4	0	• Sorting time (shaded) • Ranking functions by growth order • Big-Oh expressions • Sums and Theta • Big-Theta expressions
3	5	5 Good	3	2	0	• Assignment problem (shaded) • Page number digits (shaded) • Tower of Hanoi (shaded) • Big theta for mixed iteration/recursion • Brute force string search
4	4	4 Good	1	3	0	• Find the non-dag (shaded) • BFS_equals_DFS • Complexity (Theta) again • Topological sequence
5	5	5 Good	3	2	0	• Shellsort (shaded) • Binary search (shaded) • Insertion sort (shaded) • Selection sort • Interpolation search
6	4	4 Good	4	0	0	• Hoare partitioning (shaded) • Inorder traversal (shaded) • Master theorem (shaded) • Non-Master theorem (shaded)
7	4	4 Good	2	2	0	• Bottom-up heap construction (shaded) • Valid heaps (shaded) • Nodes in complete tree • Pre/inorder sequences
8	4	4 Good	0	4	0	• Counting BSTs • AVL trees • BST-insertions • AVL tree traversals
9	4	4 Good	3	1	0	• 2-3 trees (shaded) • Max-heap plus AVL (shaded) • AVL shape (shaded) • 2-3 shape
10	4	4 Good	2	2	0	• Linear probing (shaded) • Coin-row instance (shaded) • Brute-force vs Horspool • Dutch flag
11	4	4 Good	3	1	0	• Knapsack (shaded) • Cost of minimum spanning tree (shaded) • Edges in minimum spanning tree (shaded) • Number of different spanning trees
12	3	3 Good	1	2	0	• Huffman AGCT (shaded) • Dijkstra • Huffman codes

Following two iterations

For confirmation of quiz questions in need of attention, weekly Item Analysis reports were run for the same quizzes in the next two semesters. It was expected the question discrimination and difficulty scores for these reports would be like those of the corresponding weekly reports in the pilot semester. This was indeed the case for discrimination scores, in that students who answered the questions correctly did well in the quiz overall. There was a major difference in quiz question difficulty scores between the pilot and the following two semesters. In the pilot, some question difficulties were decided as 'easy' and others as 'medium', whereas in the following two semesters all questions have been classified as 'easy' difficulty, meaning over 80% of the cohort answered all questions correctly. Further, every quiz question was tagged by the software as 'recommended for review' due to its 'easy' classifications.

Why should the same question be classified with different ‘difficulties’ over various iterations? It was hypothesized that the disparity between iterations was an artefact of making quiz participation a hurdle requirement in the subject during the second and third iterations in 2016. Associated with the hurdle requirement came the opportunity for students to make an unlimited number of quiz attempts and, it seemed that students generally attempted the quiz as many times as they liked until they succeeded in getting all questions in a quiz correct.

This hypothesis was investigated by downloading all attempt statistics for all quizzes, for each iteration of the project. For each quiz question, students’ attempt statistics were sorted and graphed. To make a ‘like for like’ comparison of question difficulties between the pilot and later iterations, the attempt statistics for those who answered correctly on their first, second or third attempts were taken. For illustration and discussion, the week 10 quiz questions Brute-force versus Horspool question of semester 1, 2016 is shown in Figure 3. This question is representative of questions that were rated in the pilot by the LMS software as having ‘medium’ difficulty score of 72.23% (Figure 1), but ‘easy’ in the following two iterations, 92.05% and 98.65% respectfully. In this example (Figure 3), 14 students were unable to answer the question correctly regardless of the number of attempts, while the remainder of the cohort took up to seven attempts to answer it correctly. 134 students of the cohort of 178 answered correctly on their first (50), second (60) or third (24) attempt, which yields an alternative percentage of 75.3 % that the LMS would associate with ‘medium’ difficulty.

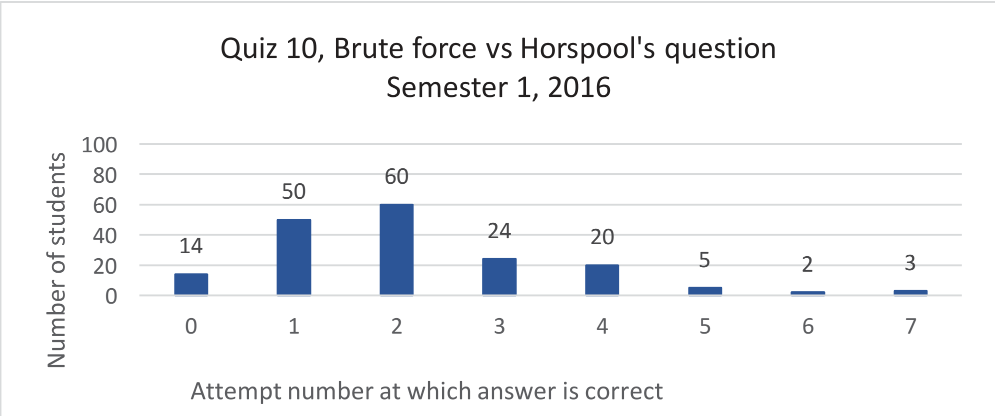

Figure 3: Number of attempt students to answer Brute force vs Horspool’s in week 10 quiz

Further investigations into the discrepancy between difficulty classifications of ‘medium’ in the pilot semester and ‘easy’ in subsequent semesters revealed that the LMS difficulty classification is extremely susceptible to change of parameters in quiz delivery. The more attempts students can make, the more likely is the LMS to classify questions as ‘easy’.

We had hoped that ‘difficulty’ classifications reported by the LMS would direct our search for the quiz questions that students found useful for challenging their misconceptions within the subject. Although it is disappointing not to be able to take LMS statistics at face value, our investigations of the raw attempt statistics for every question has pointed the way forward. Rather than dwell on the number attempts made for each quiz question, we are now looking more thoroughly at the incorrect alternatives chosen by the students in their attempts so that we may more correctly identify useful questions and common misconceptions.

Conclusion

Our experience with the use of learning analytics data from our institution’s LMS to evaluate online quizzes has been mixed. The challenge we have found is not in the acquisition of data, but in making sense of the automated reports and discerning helpful information in identifying quiz questions useful in improving students’ learning outcomes.

Mandatory quizzes in our algorithms subject have increased student engagement at motivated students to stay abreast with the subject material. However, we have been frustrated in our efforts using the inbuilt LMS question analysis tools of discrimination and difficulties to identify those quiz questions most helpful to students. In the end, the tool gave the same difficulty and discrimination classification to all questions. Analysis shows that the "difficulty" assessments are an artefact that is strongly influenced by the number of attempts that the software allows.

The issue may be broader than a particular learning analytics tool's rigidity. We would like metrics that are better aligned with the aims of formative assessment. While a focus on questions' "discrimination" values makes perfect sense in the context of summative assessment, its value in formative assessment is less clear. For our purpose, that is, for finding the "learning value" of a question, it makes better sense to study, as we ended up doing, students' response patterns. We do not have a metric to propose. However, loosely, a response pattern that, at least to us, suggests that a student has benefitted from a question is where many students fail to answer the question correctly in a first attempt, but then, perhaps based on some hint, get in right in a second attempt. When we ask students which questions they found useful, the questions they identify almost always follow that pattern.

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What can we do to better support students in Thesis?

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SESSION C3: Integration of teaching and research in the engineering training process

CONTEXT Thesis units are often considered the culmination of an undergraduate engineering degree and play an important role in addressing extra-institutional requirements, including aspects as broad as developing/assessing communication skills (EA Stage 1 Competency) and increasing student exposure to research (AQF requirements). However, even within a single institution, different schools can have markedly different approaches to these common requirements and there can be substantial variation in supervision practices even within a single school. Variations in the student experience of Thesis units have the potential to undermine the achievement of the aims of these units. To better understand the current learning & teaching practices and create consistency across different Thesis units at The University of Sydney, the Faculty of Engineering & IT has been conducting a review of Thesis units in its schools. This paper outlines the aim of the review, the review process and the recommendations of the review, particularly with regard to approaches that are most likely to ensure the achievement of the intended learning outcomes.

PURPOSE The aim of this study is to better understand the views and requirements of Thesis coordinators, supervisors and undergraduate students, and identify ways to address issues with consistency in areas such as student experience, supervision, and assessment of undergraduate theses, whilst also coping with academic workload requirements.

APPROACH A review of the current Thesis programs in the Faculty of Engineering & IT at The University of Sydney has been undertaken. Strengths and weaknesses of the current structures and practices have been identified from the perspective of Thesis coordinators and supervisors; from this, techniques and tasks that could be used to better scaffold the research experience for undergraduate have been identified. Surveys of recent past undergraduate students are being used to identify where students themselves believe that changes are necessary.

RESULTS A list of tasks that supervisors and students have found effective in supporting the undergraduate Thesis learning process will be outlined. Furthermore, both supervisor and student perspectives will be integrated into recommendations, which will include a general structure that Thesis coordinators will be able to tailor for implementation within their own schools and will identify areas where Faculty-wide initiatives have potential to further enhance student learning outcomes.

CONCLUSIONS This review's recommendations will aim to provide structure and guidance to students so that they are better equipped to gain a greater appreciation for research. Nevertheless, it is widely acknowledged that the workload of both students and supervisors is already high, so measures that will achieve this without substantial increases in workloads will be identified and prioritised in the recommendations.

KEYWORDS undergraduate Thesis; research training; surveys

Introduction

Thesis units are often considered the culmination of an undergraduate engineering degree (Holdsworth et al., 2009; Ku & Goh, 2010) and play an important role in addressing extra-institutional requirements, including aspects as broad as developing/assessing communication skills (Engineers Australia, 2017) and increasing student exposure to research (AQF, 2013). Both internal policy and external accreditation requirements often go further, and mandate a 'capstone' project experience of some form: e.g. "It is expected that programs will embody at least one major engineering project experience" (Engineers Australia, 2008).

The existing literature on final year engineering theses (e.g. Wisker, 2012, Lawson et al., 2014) highlight some areas of concern, mainly with consistency in supervision and marking. In addition, undergraduate thesis units are often students' first major experience of undertaking research, so undergraduate students often need more structure and guidance (Wisker, 2012). Lawson et al.'s (2014) interviews noted that marking consistency is a significant issue with undergraduate theses, with some interviewees arguing that supervisors can be biased or have a conflict of interest in relation to assessing students they have supervised and others arguing that supervisors must be involved in marking as they have a holistic view of a student's work. While rubrics can help with marking consistency, they also need a degree of tailoring to the project (Littlefair & Gossman, 2008). Overall, variations in the student experience of Thesis units have the potential to undermine the aims of these units (Lawson et al., 2014; Rasul et al., 2015).

This paper outlines the results of a review undertaken by the Faculty of Engineering & IT at The University of Sydney to better understand the current learning & teaching practices and make recommendations that aim to create consistency across the Thesis units run by the four different schools within the Faculty.

Overview of the Thesis Program

Engineering students at The University of Sydney undertake the thesis as 12 credit points (0.25 EFT) over two semesters during which they undertake a project. In line with AQF requirements, the thesis units aim to expose students to research as well as to have them connect their technical and design skills to broader professional capabilities within the context of a major individual project.

The thesis research process is organised into a number of sequenced assessment tasks which introduce students to different aspects of research, such as the literature review and progress report. In the literature review or proposal components, students are exposed to the existing research on their topic through identifying and analysing existing literature, interpreting the findings and evaluating the quality of the research. In the progress report or participation components, students are assessed on the process of performing research e.g. planning the research and implementation. In the presentation/seminar or thesis components, students communicate their research to peers and academics.

There are different approaches to the kinds of project students undertake and may for instance include:

- Design and construct/implement
- Collection and analysis of survey data
- Experimental tests
- Numerical simulations
- Analysis of case studies

Overall there are differences across the Engineering Schools at the University of Sydney in the assessment tasks undertaken by students. As can be seen in Table 1, there are substantial differences in terms of the timing and weighting of assessments, in spite of a relatively similar structure (proposals and literature reviews in first semester; presentations and final submission of thesis in second semester). Chemical and Biomolecular Engineering (CBE) assess each semester separately, whereas the other schools assess across both semesters and apply the same mark to both units. Additionally, Civil Engineering (Civil) and Electrical and Information Engineering (EIE) have participation components of 15% and 20% respectively, which reflect the management aspect of the thesis. Compared to other Schools, Aerospace, Mechanical and Mechatronic Engineering (AMME) give more weighting to the final Thesis submission.

Table 1: Summary of Thesis assessments

Week	Civil	AMME	CBE	EIE
Semester 1				
3			Online Quiz (5%)	Proposal (0%)
5		Proposal (0%)		
7			Literature Review/ Plan (45%)	
10	Literature Review (10%)			
13		Progress Report (10%)	Presentation/ Seminar (50%)	Progress Report (0%)
Semester 2				
7			Progress Report (20%)	
11			Thesis (70%)	
12	Presentation/ Seminar (15%)	Presentation/ Seminar (10%)	Presentation/ Seminar (10%)	
13	Thesis (60%)	Thesis (80%)		Thesis (60%)
StuVac				Presentation/ Seminar (20%)

In terms of marking, each of the schools has a policy that the final submission of the thesis is assessed by two markers, namely the supervisor and a second marker, but if the marks differ by 15% or greater, a third marker is required. A common rubric is used across the Faculty for the marking of the final submission. Presentations are also assessed by two markers, but each school has its own criteria. The marks for the other components (e.g. literature review, participation) are determined by the supervisor alone.

Depending on the nature of the project, as well as on student needs and the style of supervision, support from supervisors can include: weekly meetings with students; directing students to library resources; discussion of the requirements and expectations of the thesis unit; showing and reviewing exemplars or the provision of a thesis template; creation of project plans; provision of feedback on written submissions; and introduction to industry contacts.

Review Methodology

Information for this research was collected through discussions and an online survey. Discussions were held with the unit of study coordinators from the thesis units who identified areas which were of concern. These included: variations in quality of supervision; inconsistency in marking; and the difficulty of project assignation. Approximately 130 past graduates of the Bachelor of Engineering degree at The University of Sydney were emailed a link to an anonymous online survey to which there were 16 responses. Study data were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture tools (Harris et al., 2009) hosted at The University of Sydney. The ethical aspects of this study were approved by the HREC of The University of Sydney 2017/483.

Survey

The following questions were asked in the survey:

1. What did you enjoy most about Thesis?
2. What do you think needs improvement?
3. How useful would the following have been during your Thesis?
   a) Online modules to guide you through Thesis
   b) More tasks to support communication skills
   c) More opportunities to present work throughout the year
   d) Changes to the marking rubric
   e) More assessments/deadlines
   f) Standardisation of marking/marks better linked to WAM
   g) Group discussions
   h) Clearer expectations from your supervisor
   i) A project with strong links to industry
4. What other techniques and tasks do you think could have been used to improve your learning experience during Thesis?

Survey Results

The survey responses were received from students who had received marks of 65–91 for the Thesis units. Despite substantial differences in their Thesis marks, many students made similar comments in response to the survey and there did not seem to be correlation between their marks and the ratings on proposed changes.

What did you enjoy most about Thesis?

Many responses indicated that the topic was one of the highlights of the Thesis experience, commenting positively on “learning about things that I am really interested in” and the “[a]bility to research a fascinating topic”. Furthermore, the autonomy to work on the topic was clearly a positive experience, with a number of comments about the independent nature of the research project, e.g. “I really enjoyed the independence” and “[t]he opportunity to do individual research into a topic outside of lectures. The ability to take research into own direction”. This also had the additional benefit of giving students the “flexibility to do more work in the weeks that I didn't have much on”. Some responses also highlighted a positive experience with supervision, e.g. “relationship with my supervisor” and “[w]orking with a really good supervisor. He was really supportive”.

What do you think needs improvement?

Many of the responses commented on varying quality of supervision, with “some people hav[ing] fantastic experiences whilst others poor experiences”. Some responses commented on the availability of the supervisors, e.g. “[s]upervisors should try to make themselves available to thesis students in a reasonable capacity” or “[s]upervisors need less students each so they actually have time for their students”, whilst others added that the quality of the time with the supervisor was important, e.g. “more constructive sessions with Supervisors are required for a successful thesis”. These comments contrast with the positive comments on supervision in the previous section and clearly highlight the inconsistency between the student experience of supervision. Some students have pointed out that their supervisor (as an individual) was excellent, but also acknowledge that this is not necessarily the case across the spectrum of supervisors.

There were also comments on assessment, mainly regarding the "[i]nconsistency in marking and lack of transparency in the marking process". This is further reflected in comments regarding the lack of feedback from the thesis submission, e.g. "presentations were done and we received final mark, but no breakdown into components or feedback on research itself - what could have been done better".

The thesis units are typically taken across two semesters, with most schools weighting the assessments in the second semester much higher than the first semester. Some responses commented on the subsequent lack of incentive to work in the first semester, e.g. "[t]here could be more incentive to start your experimental work/conduct interviews earlier" and "[h]aving more presentations during the year (eg 2 min q&a) to encourage people to work through year".

Interestingly, there is a clear alignment in the concerns of unit of study coordinators and the students, especially in the areas of supervision and marking. This is likely a reflection of the fact that unit of study coordinators receive feedback from students (in the form of Unit of Study Survey results), and oversee the marks finalisation process, where significant differences in mark allocations between markers are most obvious.

How useful would the following have been during your Thesis?

Figure 1 shows the number of responses that agreed or disagreed with each proposed change listed in the survey. It can be seen that there is general agreement with the usefulness of the potential changes that were listed, with the clear exception of strong disagreement with e) more assessments/deadlines. Interestingly, the respondents who commented that there was a lack of incentive to work in first semester also disagreed with the usefulness of more assessments or deadlines.

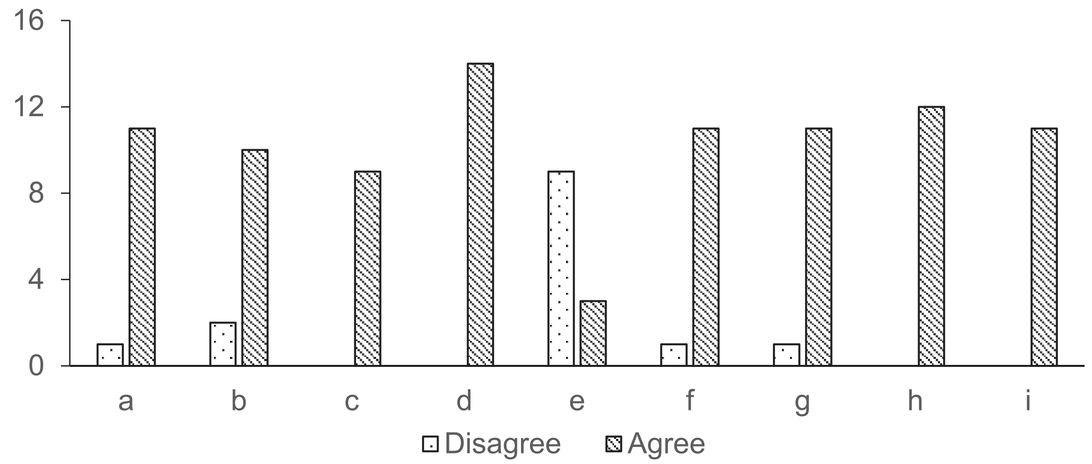

Figure 1: Agreement and disagreement with the utility of a) online modules, b) communication tasks, c) more opportunities to present work, d) rubric changes, e) more assessments, f) standardisation of marks, g) group discussions, h) clear supervisor expectations, i) project with industry links

What other techniques and tasks do you think could have been used to improve your learning experience during Thesis?

A number of respondents commented on the lack of training in how to write a thesis, e.g. "[a] presentation or a tutorial of how to write a thesis before it is written" or "some organized learning materials or workshops in using better tools (for example, LaTeX) for both word processing and citation management." This also reflects an improvement suggested by a respondent that, "a lecture when thesis starts about what a literature review is, then a separate lecture on what methodology should entail etc." should be offered. Currently, Civil and EIE organise literature review writing sessions in conjunction with the Library in first semester. According to the thesis coordinators from the respective schools, the Literature Review sessions that are run by the Library specifically for engineering thesis students are well-attended by the Civil and EIE students. Furthermore, some respondents commented on the usefulness of exposure to other students' research, e.g. "communication with other groups" and that "a mixture of group discussions and one on one feedback sessions and review" was helpful when organised by their supervisor.

Recommendations

The aim of this review is not to homogenise the thesis experience, but rather to support the improvement of the student experience and learning outcomes of the Thesis unit. Based on the data collected, the following recommendations aim to minimise structural changes to the existing units by focusing on the introduction of new elements and promoting "best practice" from across the different schools' existing units.

Conduct End-of-Thesis Student Survey on Supervision

Issues with variability in supervision quality should be assessed via an end-of-thesis survey where students can provide feedback on their supervision experience. Currently, the Unit of Study Survey provides feedback from students on their overall experience of the thesis unit, and Thesis coordinators often have a general idea of which supervisors are providing adequate supervision; however, a survey specifically on supervision would create greater accountability for individual supervisors and allow Heads of School to make an assessment on which supervisors are performing well and which need further support, scrutiny, accountability or training.

Ensure Consistency of Marking

The mandatory use of third markers was noted by the thesis coordinator to have been effective in the past; however, this is a resource-intensive practice and is not practical with the growth in student numbers that the Faculty has recently seen. Furthermore, there is general agreement from supervisors that the use of external markers for across-the-board marking would not be ideal as theses should be marked by someone with experience in the research area. There is no immediate solution to the issue of consistency of marking between two markers; however, monitoring of supervisors who consistently give high or low marks relative to the second marker or who consistently give their students marks much higher or lower than a student's Weighted Average Mark (WAM) should be undertaken. Using this information, supervisors with unusually generous or harsh assessment practices can be identified and steps can be taken to either normalise marks or to discuss the marking with the supervisor.

Provide Feedback to Students

The process of giving feedback to students at the end of the thesis should be formalised so that students receive information on their performance in the thesis unit. Currently, this process is dependent on the supervisor and internal requirements, with many schools not necessitating any feedback beyond the final mark. Feedback will provide students with further insight into their own strengths and weaknesses, as well as increase student confidence in the marking process. This could simply be in the form of checked boxes in a rubric and a mandatory one-paragraph comment from the marker, as is current practice in EIE.

Provide Thesis Writing Resources

There are a number of resources available to students at The University of Sydney to help them with their thesis writing, such as the Library and Learning Centre resources. In general, however, guidance on writing is often not considered to be the responsibility of the supervisor, but rather the responsibility of the student, and students may be reluctant to access general resources that are not tailored to engineering students.

The Literature Review sessions that are run by the Library for engineering thesis students are tailored to help students find scholarly resources and evaluate the quality of the information within the resources. Some sessions also introduce the use of reference managers, such as Endnote. The Learning Centre also runs sessions on how to write a Literature Review, but the focus tends to be on postgraduate research students, as noted by one of the survey respondents, “They have these for postgrads but I don’t understand why they don’t do it for undergrads”. Further discussion with the Library and Learning Centre is required regarding resourcing; however, these programs should be expanded across all the schools so that all students are aware that there are Library and Learning Centre resources available to them and, if organised across the Faculty, there would be greater flexibility in the timing of sessions that can be run.

Provide Templates and Exemplars

Templates and sample submissions of past student work could be provided in each school as a guide to students. Ideally, a variety of past submissions would be included to account for the differences in types of projects offered by the school. Currently, this is done at the supervisor level, resulting in situations where some students have a much clearer idea of the expectations than others. If introduced at a school level, all students would have the same base level of support and supervisors who may wish to build on the provided resources (by providing their own exemplars or by analysing the template and submissions with their students) may do so.

Encourage Video Presentations

To create incentive for students to work throughout the year (and particularly, in first semester which generally lacks assessments), students should submit a video submission of their progress and expected findings. The videos could be distributed across the Faculty for peer review and this could also be used as an opportunity to expose students to research outside of their own project. Although the student survey suggested that more assessments would not be beneficial, a first semester, low-weighted assessment would alleviate some of the concern with the additional workload. Furthermore, this cross-School initiative would align with The University of Sydney’s Strategic Plan, which includes a greater focus on multidisciplinary activity.

Include Poster Presentations

An unassessed poster presentation session is another way in which students can be exposed to research outside of their own project. Both staff and students would have the opportunity to interact with poster presenters and, would have the opportunity to learn more about projects on offer and about potential supervisors. This would benefit penultimate-year students as well. In the past, poster presentations have also been attended by industry representatives. Coordination across the Faculty to run poster presentation events on the same day would give students the opportunity to see research outside of their own school.

Conclusion

This research identified issues mainly concerned with supervision and marking, but also feedback, resources and exposure to the research being undertaken by their peers. Positive aspects identified from student surveys suggests that the respondents generally agree that, aside from additional assessments, the provision of additional structure and support during the thesis unit would be beneficial to them. This review recommends that support for students be provided by better promotion of thesis-writing resources and the provision of templates and exemplars. Furthermore, consistency of supervision and marking should be addressed via an end-of-thesis student survey on supervision and monitoring of lenient markers. More opportunities to present their projects and, conversely, gain a better understanding of research outside of their own project should be given to students, as well as better feedback on their final submission.

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Assessment of Self-Management Skills in a Project-Based Learning Paper

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SESSION C2: Interdisciplinary and cross-disciplinary engineering programs…

CONTEXT Assessing student learning outcomes as evidenced through their technical skill development and grades in project-based courses is well-described in the literature. However, most work to date concentrates on students' learning achievement rather than their learning process, leaving students to learn how to manage the projects that they are assigned largely on their own. Students therefore consider their technical achievements to be the desired outcomes, even though staff may list non-technical skills such as "time management" or "self-organisation" (self-management skills) as formal learning outcomes, working on the theory that the student must have managed themselves to have achieved their technical outcomes. However, in order to meet the imperatives for quality engineering graduate attributes and professional competencies, educators need to attend to and make explicit the ways important non-technical skills can be facilitated and valued in project-based courses.

PURPOSE This study aimed to investigate the effectiveness of implementing a management-based assessment structure to promote engineering students' self-management skills as part of learning to organise their work in a final year entirely project-based course.

APPROACH In a final-year, entirely project-based (students working solely on several prescribed projects), mechatronics paper, we employed a postgraduate student with a business degree to take up the role of a "demonstrator manager". Technical assistance was provided to students through lectures and lab work but organisational assistance and reporting was provided by the "demonstrator manager". About one-third of the marks for the paper were to be awarded by the "demonstrator manager" based on how well she perceived each student to be planning and executing their projects. Key to the process is the fact that the manager did not know much about the technical details of the projects, forcing the students to plan their work, explain milestones in consultation with her, and explain their progress to an "outsider". Data were collected from end of the course survey and interviews with staff and students as well as students' progressive achievement in the course.

RESULTS Preliminary observations indicate that students were at first unsure and rather casual in their response to this new assessment process. After evaluative feedback was given justifying marks they received (or did not receive), students responded by taking the need to report much more seriously. The most positive feedback was received from students whose first language was not English. This new assessment process coupled with the role of the "demonstrator manager" have value in helping students make explicit the learning process (i.e. learning of important self-management skills in this study) pivotal to the successful conduct of their projects.

CONCLUSIONS This initial study revealed the potential of having management-specific assessment and business-related demonstrating staff in undergraduate engineering project-based classes. This will offer students valuable insights in preparing for engineering industries that are increasingly incorporating interdisciplinary expertise and ideas to solve complex issues.
KEYWORDS Problem-based learning, assessment, non-technical competencies

Assessment of Self-Management Skills in a Project-Based Learning Paper

Introduction

Assessing student learning outcomes as evidenced through their technical skill development and grades in project-based courses is well-described in the literature. Common assessment approaches used include peer- and self-evaluation (van den Bogaard & Saunders-Smits, 2007), prescriptive processes (dos Santos, 2016), and learning rubrics (Szarka & Brestenská, 2012). Most work to date concentrates on learning achievement rather than learning process, leaving students to learn how to manage the projects that they are assigned largely on their own. The students consider their technical achievements to be the desired outcomes, even though staff may list non-technical skills such as “time management” or “self-organisation” (self-management skills) as formal learning outcomes, working on the theory that the student must have managed themselves to have achieved their technical outcomes. However, in order to meet the imperatives for quality engineering graduate attributes and professional competencies detailed in the Washington Accord (2013), educators need to attend to and make explicit the ways important non-technical skills can be facilitated and valued in project-based courses. This is pivotal if graduates are to develop the capacity for self-directed lifelong learning and to function effectively in ever changing and increasingly complex engineering work contexts.

Research Context and Design

The Course

This study is based at a New Zealand university within its School of Engineering. The Mechatronics paper/course ENEL417 is offered to final year electronic engineering (EE) students and is intended for advanced students to integrate their learning of concepts from earlier three years of coursework and apply them in a series of three projects, each increasing in complexity and building on the learning of earlier projects. The course is entirely project-based. Students work mostly independently on their projects and are allocated lab workspaces and equipment simulating environments in real-world engineering workplaces/industries. Classes in the paper are scheduled for two hours each day of the week for an entire semester but students have the flexibility of accessing their workspaces and equipment in the laboratory (lab) whenever they need them, and most do. The course typically has an enrolment of between eight and 16 students each year. Students are required at various stages to program microcontrollers, design and build interface circuits, process sensor inputs, drive actuators, transmit or receive data, parse data packets, etc.

Traditionally the course is convened by a single lecturer (Lecturer 1) who offers technical assistance through lectures and lab work to facilitate students’ developing and successful construction of their projects. The lectures highlight the theoretical understanding and technical ideas students will need to apply in their projects. The lecturer would also run short mini-lectures during labs as and when needed to support students if students persistently face an issue in their project work; examples might include the application of sub-sampling or best-practice in coding delays. As the lecturer is an expert in the area and had been teaching the course for quite some time, he is able to quickly pick up students’ assumptions and misconceptions and address these early in the course to guide their thinking. The lecturer felt this may not be benefitting students’ learning of important non-technical skills (i.e., planning, self-management and problem-solving skills). Students had difficulty planning milestones and articulating their thinking. As Glaser (1987) pointed out, experts differ from novice learners in terms of “knowing what one knows and doesn't know, planning ahead, efficiently apportioning one's time and attentional resources, and monitoring and editing one's efforts to solve a problem" (p. 13). The lecturer was thus keen to investigate strategies that would enhance students becoming aware of, and articulating their own planning, managing and problem-solving aspects of their project. The lecturer's idea was to enhance the course assessment structure to include a component requiring students to report on their planning and progress to staff (demonstrator) from a management background (the assessment innovation) rather than technical, as occurs in industry.

The Intervention

This study focuses on the assessment innovation implemented in ENEL417 Mechatronics. When the study was conducted, the course was co-taught by two lecturers (Lecturer 1 and Lecturer 2). A science student with a previous commerce degree was employed as a course tutor to take up the role of a "demonstrator manager" throughout the course. The lecturers took turns to offer technical assistance to students through lectures and lab work but organisational assistance and reporting was provided by the "demonstrator manager". About one-third of the marks for the paper was awarded by the "demonstrator manager" based on how well she perceived each student to be planning and executing their projects, and the timeliness and comprehensibility of their reports. Key to the process was the fact that the demonstrator manager did not know much about the technical details of the projects, forcing the students to plan their work, explain milestones in consultation with her, and explain their progress to an "outsider" (see Appendix 1 for the sample questions that the demonstrator manager used to probe students to be more explicit in thinking through their project and the marks allocated). Students reported their progress to the demonstrator manager on a weekly basis. The demonstrator manager would drop in several times a week or every other week during students' lab hours. In these reporting sessions, students meet individually with the demonstrator manager to provide a quick update of their work, go through issues they have encountered and provide an outline/plan for troubleshooting and achieving their next milestone. Students could email their progress if they missed seeing the demonstrator manager. The paper organisation strategy is based on Packard's (1985) Management by Walking Around.

This demand for milestones and progress reporting forces students to break down the process of managing their project into small steps with specific goals that they will need to achieve within the week/a timeframe to develop their project. This strategy shares characteristics with the notion of setting *subgoals* in situations where one is required to take small functional steps to solve a complex problem. Teaching learners to identify and achieve subgoals have been evidenced to increase their success at solving novel problems (Margulieux & Catrambone, 2016). The assessment innovation in our study was therefore intended to be authentic and to function as a learning tool in itself.

Research Design

This exploratory qualitative study therefore aimed to investigate the effectiveness of implementing a management-based assessment structure to promote students' self-management skills as part of learning to organise their work in their project-based course. It case studies staff and students' experiences in the final year Mechatronics paper to obtain their views on the new assessment strategy and highlight any suggestion for enhancing the assessment innovation.

Participants

Nine out of 11 EE students who enrolled in the course consented to participating in the study. They completed the end of the course survey. Of these nine, seven students attended the focus group interview. The study received ethical approval from the University's Human Ethics Committee and all participants participated in the study on a voluntary basis.

Data were collected through lecturer and demonstrator manager interviews, students' progress achievement in each project, demonstrator manager's feedback to students, student focus group interview, and students' survey evaluation of the course. The survey was conducted online via Google Forms and was collated and analysed using Microsoft Excel software while the focus group interview data was thematically analysed to identify emerging themes (Braun & Clarke, 2006). Each form of data was analysed separately and then triangulated to address the research aim.

Findings

We report the findings from the student achievement first, followed by the themes emerging from the survey and interviews. Themes regarding the value of the assessment innovation will be highlighted first followed by challenges and suggestions for enhancing student learning. Each theme will be evidenced by student data and corroborated with data gathered from lecturers and tutor.

Student achievement

Figure 1 illustrates the marks awarded by the demonstrator manager for each student for the three projects, based on the assessment innovation.

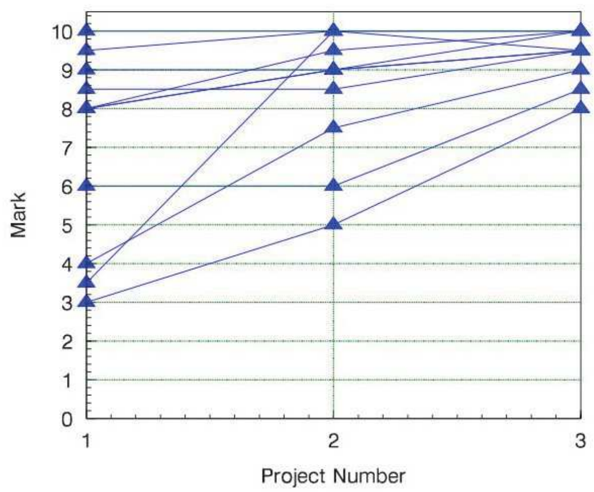

Figure 1: Individual student marks for the assessment innovation based on the three projects

The marks in Figure 1 summarise the outcomes: The figure shows a clear overall improvement in student ability to explain and report on their project over the duration of the course. Every student improved from project to project, with the single exception of one student who scored 100% in the second and 95% in the third project. Three of the cohort went from failing in their ability to explain what they were doing in the first 3 weeks to A grades. The lecturers consider this simple quantitative summary to reflect the success of the intervention in improving students' non-technical performance.

Lecturer 2 commented on the benefits for especially the average achieving students including those for whom English was not the first language:

> *It worked really best for the average students. The good ones already had it under control. It's the ones that were in the middle range who benefited most. The weak ones probably benefited but still struggled a bit….There's a definite trend of improvement, most had got it by the second one [project] but by the third one they've all pretty much got it. The non-technical skills, they [students] are starting to get more organised, aiming for the deadline. The students struggling to achieve the midway assessment in the third project by the end had caught up. They all passed that last bit comfortably (Lecturer 2).*

The demonstrator manager affirmed students' progress over time and the fact students had time to consider the process of working through their project:

> *In the first project, it was 2 or 3 students who did a very good job, majority did an average job and 2 students did really poorly. But then the second project, this increased to 4 students who did a very very good job who got full marks, 3 to 4 students did a reasonably good job, no one failed. And for the last one everyone did a really good job of explaining. I think the [last] project was longer as well and hardest and they had a lot of time to think about it. They had time to think about the process thoroughly so they were able to explain better, it's not just my involvement. I hadn't expected such a great improvement over a short period of time (Tutor).*

Benefits to Learning

Students perception of the assessment innovation

In the student survey, all students reported that the assessment innovation was helpful to varying degrees in developing their project. Three students reported it was 'Very Helpful', four reported 'Helpful' while one reported it was 'Somewhat Helpful' to their learning. When asked about the skills they think they have developed as result of the assessment innovation, a majority of students reported that it was 'Being able to explain what I know/understand to someone from a non-Engineering background' (6 students), followed by 'Gaining a better understanding of how to manage my project' (5 students), and, 'Finding out which concepts I do and don't understand' (4 students) (see Figure 2).

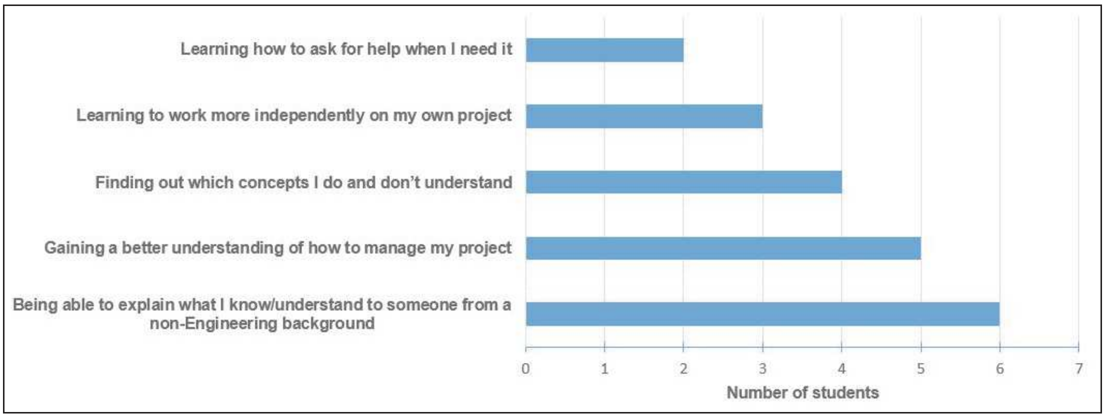

Figure 2: Skills students reported developing due to the assessment innovation

Four key themes emerged from the findings. These show the value of the assessment innovation.

Becoming an engineer

All participants considered the identified skills integral to becoming a professional engineer and thought the assessment innovation went some way towards supporting students' developing these. Lecturer 1 valued students being able to communicate and demonstrating their thinking to others:

> *Many papers in engineering ask students to do some lab work and write up a report. This hardly happens in real EE companies. You keep a lab book and you convey the outcome of some measurement to your colleagues in a meeting. You don't write a report and send a memo around. It just doesn't happen. One of the key skills you need is the ability to come up with some lab measurement and go 'We have been doing this wrong and we need to [whatever]... or you say that, I did this and it worked quite well'. So the way students communicate is not by writing report to people. It's by telling them what is going on and showing them here is the proof (Lecturer 1).*

Lecturer 2 highlighted skills such as self-learning, collaborating with others and communicating ideas clearly:

This project-based work is quite good. We are preparing students for a professional degree for the workplace and therefore it is appropriate to start them to think about 'how do I practice the art of the workplace in the industry, to get a feel for it. If they can't organise themselves they can't make progress. As an engineer you should be able to self-learn, work out what you don't know, what you need to learn for the project and why. You should be able to work together with others, team effort, put together a whole product. So they need to be able to communicate and understand others. When they start off they may not be able to manage others but they should be able to organise themselves (Lecturer 2).

The demonstrator manager added that key skills in becoming an engineer was problem solving, communication and being customer-focused:

If you are going to invest your time, money and training for an engineer, he/she should be able to set milestone, be able to solve problems, or give a time frame to the supervisor about the problem they have encountered. Because the customer wants the product in a certain timeframe. It's a very important skill to be able to communicate to the customer where you are at in the project making process. Why would they [customer] choose your company if they can get the same product but with better communication from another company who is keeping in touch with the customer, taking the customer's needs into account (Tutor).

Simulating a real-life workplace environment

In the survey and focus group, students affirmed the assessment innovation offered them a realistic experience typical in the engineering workplace. They highlighted advantages such as having to communicate ideas to a non-technical person and setting milestones. Two student responses from the open-ended survey were:

It was helpful to have a person that has a tangential understanding of what is happening but requires updates on what we were doing, this is a good comparison to what we will expect in the workplace.

A condition to ease the process of communicating their ideas was that the despite the demonstrator manager having minimal technical knowledge, she at least needed to have some basic technical understanding. Students in the focus group made this clear:

It made it easier to explain things, we didn't need to go really basic, we could talk about our components and she'd understand. There are certain things you can take for granted that she knew; how components work, for instance using capacitors to filter things out. I don't have to stop and explain [otherwise] it will slow us down as well. You do need a certain degree of technical knowledge (Student, Focus group).

Maintaining regular planning and progress in project work

Students appreciated having to plan and maintain regular progress on their project work through the new assessment structure. Student quotes highlighted their becoming aware of developing time management, planning and goal setting/milestones and problem solving skills:

It [Talking] helps realise it [project] rather than it being just an idea, what you actually need to do, your plan…also the scale of the project, it's actually a lot of parts to it. So you can appropriately plan for it (Student, Focus group).

The management component to this course was helpful for me in managing the timeline of the my project in the way of providing milestones to the manager also help to keep my progress on track as I would aim to achieve those milestone by the next meeting (Student, survey).

I was so focused on what I was doing and not thinking about what it [part of the project] will be building onto but …when you talk to the tutor and she asks 'What's next?' then you actually stop and think, 'Ok this is still what I have got to do'. Initially I didn't really set up milestones but when I started talking to her then I can tell her what it is going to look like. Milestones help to put the whole project in perspective, explaining to her [tutor], it quickly became apparent whether you are ahead or behind schedule (Student, focus group).

The demonstrator manager confirmed that all students' developed skills in self-setting of milestones, time management and written and oral communication (e.g., setting up checklists) towards the end of the paper:

> *By the end, a majority of students had small self-set milestones as opposed to the lecturer's general milestones. For them to break it down into small goals for themselves, this improved significantly for everyone (Tutor).*

> *Their [Students] time management improved - when they said, 'I could fix this problem in 3 days', I'd come back in 3 days and it was fixed and they are on to the next problem [for the final project]. The first project, time management was lacking (Tutor).*

> *The best result I saw was their checklist through email. They would send me a checklist and they would print off the checklist or keep it up on the screen and show me each time I came in, [explaining] 'This is where I am at, I am doing this for this particular reason, for example, I am soldering this circuit because I want to read data off the tracks…' Every student did this towards the end (Tutor).*

Deeper understanding of technical concepts and communicating these clearly

All students thought the assessment innovation supported their thinking more deeply about their technical ideas. Having to communicate to a non-engineer forced students to explain their ideas explicitly and clearly without using 'geek speak', in doing so students realised potential flaws in their own thinking and began to plan ways to problem solve their project work. Students in the focus group alluded to these ideas:

> *As electronics students we spend a lot of time on our own in our work, communicating with one another, it was good to have someone to practice communicating with someone a bit more 'real'. Our communication is mostly what we hand in…assignments, reports. It's [the assessment innovation] not something we normally deal with so it's great because when we get into the workplace, we'll be having to report to quite a few people (Student).*

> *You are trying to change the language, you are not thinking of specifically coding language. It's a separate thing, so you are thinking of slightly different perspectives. You don't need to consider how to build it on the schematic, it's just that thinking in simple language, 'What I need to do to get the motor driving is…' It does change the way you think in the language you won't normally use (Student).*

> *Explaining how you are going to do something to someone early in the project can help outline flaws in your thinking (Student).*

The demonstrator manager reported students communicating more succinctly towards the end of the paper in terms of time and quality of communication:

> *Being able to communicate succinctly about their project. It would start off with 20 minutes per person in the first project but over time this would go down to 5 to 10 minutes because they would just tell me what I needed to know about their project (Tutor).*

Challenges and recommendations for improvement

Students raised three aspects that could be improved when implementing the assessment innovation: clarifying expectations about the innovation, flexibility in reporting to the demonstrator manager, and obtaining regular feedback about progress.

Clarifying expectations

A key challenge in the introduction of the assessment innovation was the unclear expectations about how it was going to be played out and clarification of the demonstrator manager's role and responsibilities. It was unclear whether her role extended to offering technical guidance.

> *Be more clear about what is needed or have a handout/guideline, this will be helpful for future cohorts. The lecturer could prepare a doc that can be uploaded to Moodle [class website] explaining what is needed/criteria for marking/what needs to be in the discussion content with the tutor, etc. (Student Focus Group)*

Flexibility in reporting

In the focus group, students mentioned wanting more flexibility in being able to do more reporting via email to the demonstrator manager as they could not always meet with her on a face-to-face basis:

> *Being able to email their progress to the tutor apart from the face-to-face discussions as coding is a hard work and you don't always get it right, sometimes you fall back two steps behind and it appears as if we have not progressed from the previous meeting with the tutor when she comes into the lab. We felt this affected our marks.*

If a face-to-face meeting was to be held, students thought they could get better organised if they had a pre-arranged fixed time/day of reporting to the demonstrator manager:

> *She could let us know (have a fixed time to see each person) so we know to prep for her coming. Otherwise her coming in was a bit random and we are at times scrambling for what to say to her. You never know when she was coming from the 5 lab times but we may not fit into those times, some of us work away from home or late night.*

Obtaining regular feedback about progress

Although students appreciated their regular reporting to the demonstrator manager on their progress, they had hoped that she would provide them with how they were progressing including her grading of their progress. A sample student survey quote was:

> *It would have been good to get some feedback of how well we were communicating with the tutor throughout the projects instead of just at the end. This would be so that we could work at improving during the current project instead of the next project.*

Discussion and Conclusion

Science and engineering graduates are expected to have strong communication skills, practical ingenuity, and good written and oral communication skills (Coll & Zegwaard, 2012), as well as an understanding of business practices and a sense of social, ethical, political, and human responsibility (Campbell & Zegwaard, 2015). Tertiary institutions have been tasked with the need to offer relevant and authentic curricula to enable students to develop these competencies. The authors consider this innovation to have been very successful. We have presented quantitative and qualitative evidence showing that the innovation of separating the technical and reporting assessments, and having the reporting handled by a "demonstrator manager" worked surprisingly well.

Although this small study may not necessarily generalise to other contexts, it is hoped that the insights gained can inform other educators interested in pursuing the assessment innovation to consider ways of implementing it in their practice. We hope to extend this study with the aim of characterising what is required in the "demonstrator manager" role, and testing it in larger classes.

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Appendix 1. Sample tutor/demonstrator manager questions

At the beginning of a project:

1. Tell me about the project.
2. What is your primary plan to handle the project?
3. What milestones have you set for the project?

Middle of the project:

1. What milestone have you achieved thus far?
2. How did you achieve it? Can you show me some demonstration of your device when you achieve an actionable milestone?
3. (Usually they'll run into a problem) What is the problem? Do you know why it is occurring? and what actions are you going to take to resolve the issue and within what time-frame?
4. If you cannot resolve it within that time frame, do you have contingency plans?

End of the project:

1. How did you fix your problem?
2. Can you show me a working demonstration of the device?

<u>Marking criteria</u>

1. Student understanding of their project [1 mark]
2. Student ability in planning and organising (i.e. milestones with time frames) [4 marks]

3. Student ability in explaining issues that they ran into [2 mark]
4. Student ability in resolving project issues [2 mark]
5. Student providing evidence of their progress [1 mark]

Integration of Applied Research in Polytechnic Engineering Education

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CONTEXT

The engineering programs in Ara are progressively moving towards modern teaching pedagogy and new learning environment focusing on enhanced critical thinking and engagement. This includes further integration of research in the education process. Future modern industries will have an increasing demand for a workforce with a high level of critical thinking, transdisciplinary knowledge and with novel and adaptive thinking skills. Integration of research in the education process is essential to remain up to date and ensure innovation and relevance to future jobs.

PURPOSE

The purpose of this paper is to discuss the opportunities and possible strategies to integrate research in the education process (undergraduate level) with a focus on the role of Polytechnics.

APPROACH

The approach considered here includes aligning the student final year projects with practical short-term industry-sponsored research projects. Research elements were gradually integrated in the process and assessments of MG7101 course (Engineering Development Project).

RESULTS

The quality of student projects and level of industry engagement improved leading to a number of quality assured publications. The experience has also been appreciated by industry and the students involved; following is an example of positive comments from one of the recent graduates whose project led to a conference presentation and publication:

"It was the first real conference I had ever attended and while it was a bit nerve-wracking presenting, I came back having learned a whole lot. I encourage anyone undertaking a research project for their BEngTech to strive for excellence, with the aim to get your work published and attend a conference to present the findings. It was hugely rewarding for me and counts towards professional recognition with IPENZ".

CONCLUSIONS

The outcomes obtained to date are promising and show good potential in the Polytechnic system to provide an enhanced research integration and practical research outputs.

KEYWORDS

Integration of research, Polytechnic research, Engineering education.

Introduction

Today, Research and Development (R&D) is an integral part of the industry resulting in an increasing demand for the graduates with high levels of sense-making, data analysis and critical thinking skills. Integration of research in the education process is essential to remain up to date and to ensure innovation and relevance to modern and future jobs. The abilities to interact with data, analyse patterns in data, make data-based decisions, and use data to design for desired outcomes are some of the fundamental abilities demanded by future industry and businesses (Davies, Fidler and Gorbis, 2011). Therefore, integration of these skills in curriculum cannot remain limited to postgraduate levels but should be gradually incorporated in the undergraduate education including the Polytechnics. Many Institutions are trying to increase the undergraduate exposure to research both inside and outside of the classroom through various individual, departmental or institutional initiatives (Jenkins & Healey, 2005).

Institutes of Technology and Polytechnics (ITPs) in New Zealand are government-owned tertiary education organisations that deliver technical, vocational and professional education. ITPs offer diplomas, degrees and limited post-graduate qualifications. Six major Metropolitan ITPs also promote research, particularly applied and technological research. Ara Institute of Canterbury (Ara) was created in 2016 when education providers CPIT and Aoraki Polytechnic merged. The Bachelor of Engineering Technology (BEngTech), and the New Zealand Diploma of Engineering (NZDE), in either Mechanical, Civil, or Electrical disciplines, are among the programs offered by Ara.

Traditionally, ITPs delivered graduates with pre-employment training in the skills needed to service the core and basics of the economy. However, in recent years, the ITPs need to be able to meet the needs of industries and companies which are moving towards international markets with more complicated products and services (Sissons, 2010). The engineering programs at Ara Institute of Canterbury, as a major metropolitan ITP in New Zealand, is rapidly evolving to expand its research capabilities and to incorporate research and innovation in its education system.

The purpose of this paper is to discuss the opportunities and possible strategies to integrate research in the undergraduate education process with focus on the role of Polytechnics. The fundamental research skills are gradually embedded in the education process in the civil engineering courses at Ara and the final year student projects are systematically integrated with industry-sponsored short-term research projects. In this paper, the approach and some preliminary outcomes obtained to date are discussed.

Research at Undergraduate Level

In recent years, there has been a growing number of publications internationally related to the research integration in the undergraduate level such as those by (Healey, 2005; Jenkins & Healey, 2005; Hoddinott & Wuetherick, 2006; Wuetherick, 2007). Among these, several researchers have proposed methods and models to describe the different ways in which research and teaching can be linked. Two well-known models are those proposed by Healey (2005) and by Turner and Wuetherick (2006). For example, as shown in Figure1, the model by Turner and Wuetherick (2006) is based on four categories, ranging from teacher-centred to student-centred strategies.

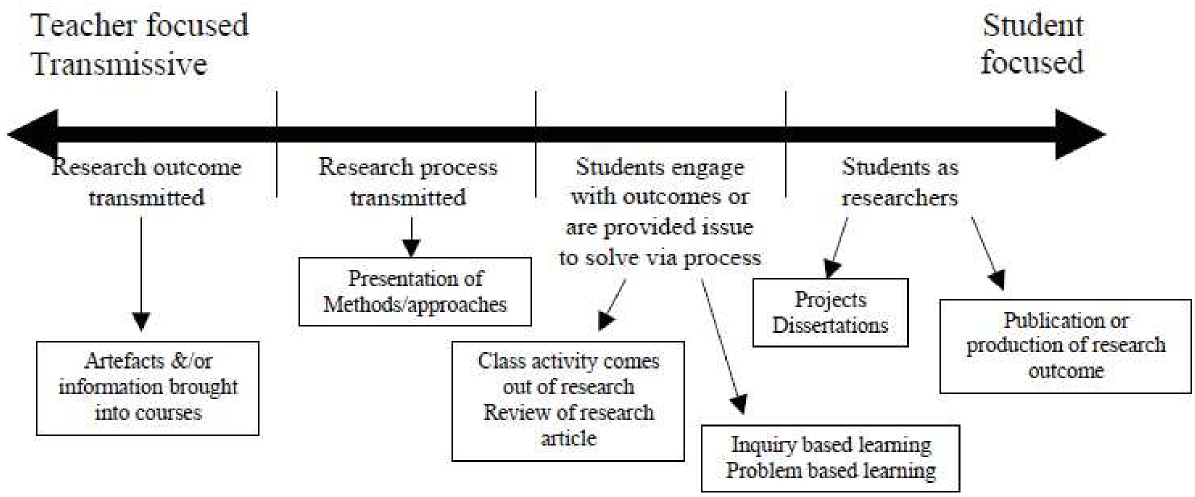

Figure 1. Model by Turner and Wuetherick (2006) linking research and teaching

In the teacher-centred concept, the teacher presents and discusses the research findings, outcomes or research methods to the students. However, in the student-cantered approach, the students are actively engaged either through class activities and problem-based learning approaches or through full engagement in a research project, which can lead to quality assured research outputs or publications.

The project-based and research-based class activities can be an effective approach to introduce research elements in undergraduate level in both universities and Polytechnics. These approaches have been employed as a tool for integration of research in undergraduate programs in some institutions such as those reported by (Kosse & Hargreaves, 2004; de Silva, 2004; Cartwright, 2012; So, 2013).

On the other hand, full engagement of undergraduate students in a research project can be dealt with quite differently in universities and Polytechnics. In research driven universities, the undergraduate students will have opportunities to join postgraduate students or to engage in short-term funded summer research projects. This method is not possible in Polytechnics due to a limited number of postgraduate students (if any) and also limited research funding and resources available to Polytechnics compared to the universities.

However, Polytechnics can focus on their fundamental strength, which is the link with industry. The majority of lecturers in the Polytechnic system have previous direct industry experiences; more importantly, a large proportion of Polytechnic students work part-time in a relevant local industry or are sponsored by their employers. These close direct connections provide a great opportunity to engage the students in industry-initiated research projects in particular short-term applied research.

Integration of Research in BEngTech Civil Program at Ara

Bachelor of Engineering Technology (BEngTech) is a three-year programme comprising core and elective courses. To complete this degree, the students are required to complete a minimum 360 credits (each credit worth 10 hours' effort). The BEngTech in Civil discipline at Ara offers specialisations in Structural, Water & Waste, and Transport infrastructure.

The Department of Engineering and Architectural Studies, aligned with the major strategic plan of the Ara Institute of Canterbury, is rapidly evolving to move towards modern student-focused and student-centred learning strategies and also to expand its research capabilities incorporating research and innovation in its education system. To move towards these objectives, within the last two years some changes were implemented in the BEngTech-Civil Engineering Program. The main aims of these changes were to shift from traditional pedagogy to modern student-centred methods to increase the students' participation and engagement and also to increase the integration of research in the education process. The two major strategies employed include:

1- Increasing the use of Problem-Based and Research-Based learning concepts in the Civil Engineering courses including the embedment of the fundamental research skills in the process.

2- Defining Research-Based final year projects for the Civil students with focus on short-term practical industry-supported projects.

In this paper, we focus on the approach and the preliminary outcomes related to the final year student projects. The final year student projects in ITPs are offered through MG7101 course (Engineering Development Project) in all BEngTech disciplines. The project course is generally regarded as a substantial capstone course with 30 credits where the students are expected to spend minimum total 300 hours over one year on the project. The course aim and learning outcomes are shown in Table1. Within the last three years, the size of Civil cohort enrolled in this course has been within the range of 10 to 15 students across the three specialisations (Structural, Water & Waste, and Transport infrastructure).

Table1. Aim and Learning outcomes of MG7101 (Engineering Development Project)

Aim	To enable students to investigate an engineering problem; to propose, specify, design and develop a solution and where feasible, to construct and test a prototype.
Learning Outcomes	- Synthesise a solution for an engineering problem. - Complete a project to a specified standard. - Design, project manage and evaluate a concept/model/product. - Use software application packages as an engineering tool, if required. - Communicate effectively with customers, peers, technicians and engineers.

The Assessment Schedule of the course is shown in Table 2. The students are also provided with detailed guidelines and marking schedule for each assessment item.

Table2. MG7101 assessment schedule

No	Assessment	Type	Weight
1	Documentation 35%	Project Proposal	10%
		Preliminary (progress) Report	20%
		Project Journal	5%
2	Presentations 15%	Mid-term oral Presentation	5%
		Poster	10%
3	Engineering problem Solution 50%	Final oral Presentation	5%
		Final Report	45%

As shown in Table 1, the Learning Outcomes of the course are fairly general and open to interpretation. Traditionally, at Ara (formerly CPIT), this course (particularly within the Civil Discipline) was delivered with high emphasis on producing a physical model or on conducting fully experimental investigation or tests.

However, since 2015 in the Civil Engineering program this process was modified to integrate more in-depth research elements in the course including the below changes:

- Focusing on a comprehensive literature review (national and international literature) and the need to refer to scientific journals and technical papers throughout the project. The marking schedules were modified to increase the proportion of marks assigned to the literature review compared to the marks assigned to timeline and project cost schedule sections.
- Lifting the expectations in terms of the level of data analysis and analytical calculations required for the project.
- Setting the requirements for incorporation of computer simulations along with the experimental works where relevant.
- Encouraging and supporting the students to find industry connections for their projects.
- Encouraging and supporting the students to produce a quality assured publication (either a journal or conference proceeding paper) at the end of their project.

In the proposal stage, the students are required to approach industry and conduct a thorough research to find a suitable topic. The students who are employed or sponsored by employers in relevant industry are asked to investigate different sections and teams within their company to find a specific problem that needs investigating. The topics should then be approved by the principal supervisor based on their technical merits.

The projects should involve either an experimental investigation or computer simulation or both (depending on the topic) along with theoretical/analytical calculations. The students who are unable to find a link in industry are required to work on projects defined by the supervisor. Moreover, depending on the nature of the project, some projects are defined as a group project where the students work in pairs.

When the topic is tentatively approved by the supervisor, the students are required to submit a detailed proposal document containing the objectives, problem statement and a comprehensive literature review. The Proposal also includes the initial proposed methodology plus a timeline and cost schedule (for experimental projects). The students are provided with detailed guidelines and marking schedule for the proposal and for other assessment items throughout the project.

For the industry-initiated projects, after the project is approved by the supervisor, a meeting is arranged between the student, supervisor and the industry representative to clarify the scope and process. The industry contact is considered to act as an associate supervisor for the project. Throughout the project, the student has regular meetings with the main supervisor (Ara) and the associate supervisor (industry partner) independently. However, at critical stages of the project (depending on the need), joint meetings between all parties involved are arranged to ensure both the Ara supervisor and the industry contact are on the same page about the scope and direction of the project.

Results and Discussions

In this paper, the number of publications emerged from the student projects, the sample qualitative feedbacks and the sustained industry support are used as evidences of success. Implementing the above approach in Civil Engineering final year projects, the quality of outcomes and level of industry engagement have significantly improved. The outcomes obtained to date are promising and show good potential in the Polytechnic system to provide enhanced research integration and practical research outputs from undergraduate student projects.

For the first time in the BEngTech program (Civil) in the Ara Polytechnic, two quality assured publications emerged from student projects in one year (2015). Multiple papers are also currently in preparation based on some of the student projects undertaken in 2016. Additionally, currently in 2017, there are multiple civil student projects being undertaken sponsored by industry. Such achievements in terms of industry engagement and number of publications obtained directly from undergraduate student projects are rare.

Below are two sample industry-sponsored BEngTech civil/structural student projects conducted in 2015 that resulted in quality assured publications and one sample Civil/water student project currently being undertaken.

A) Experimental Assessment of a Supplementary Uplift Restraint Bracket for Residential Building Construction

The project was initiated by a local civil engineering consulting in Christchurch (Eliot Sinclair) to investigate the strength and failure characteristics of a specifically designed supplementary uplift restraint bracket for timber shear walls. The bracket is commonly specified by engineers for residential dwellings. In this research, multiple tests were designed and undertaken on the brackets under axial tensile force to examine the structural performance of the bracket components. The company provided funds for purchasing the materials and preparing the test samples while Ara provided the testing equipment. The project provided valuable practical results for the Eliot Sinclair engineers and also resulted in a publication in an international conference proceeding.

B) Evaluation of Epoxy Injection Method for Concrete Crack Repair

The project was initiated by Opus Consultants Ltd, (Blenheim) in Christchurch to investigate the reliability of using epoxy in concrete crack repairs. The use of epoxy resins for repairing concrete cracks is a common method to restore cracked concrete structures in New Zealand. In this research, the effectiveness of three chosen brands of epoxy commonly used in industry in New Zealand to repair cracked concrete beams were investigated. Multiple unreinforced concrete beams were tested before and after epoxy repair under vertical loads (flexural load) to determine the effectiveness of the epoxy to restore the structural strength or continuity of the beams. Opus provided access to their lab and the necessary materials to produce the test samples and the tests were undertaken in the engineering lab at Ara. The project provided valuable practical findings and also resulted in a publication of a journal paper.

C) Planter Box Rain Garden and Zinc Removal from Addington Brook Catchment

This project was initiated by Environment Canterbury in Christchurch to investigate, design and evaluate an appropriate solution for storm water treatment. Poor water quality in the catchment during rainfall event has been a growing subject of matter in Christchurch. This research investigates the potential treatment system for removal of heavy metal contaminant especially Zinc concentration. Four different treatment systems are studied with respect to sustainability pillars. Different filter media are designed for Zinc removal purpose in a planter box and the storm water collected from the discharge of old galvanised and new galvanised roofs is tested in the Ara lab. Environment Canterbury is involved in various stages of the project.

The above approach has been highly beneficial for the companies involved as evidenced by their sustained support in 2015, 2016 and currently in 2017 through different projects. The researched topics are completed within a one-year period with minimum cost as opposed to postgraduate level research which can take more than three years with relatively high expenses. The experience is also greatly valuable for the students as they get to experience working on a topic that is of direct interest to local industry plus the possible outcome in terms of a conference or journal publication.

In the industry-initiated projects, some additional hours were required to be assigned by the supervisor to manage the industry contacts and to arrange the joint meetings when needed as the project progresses (for instance at major millstones). However, overall this did not have a significant effect on teaching load and supervision hours.

Considering that the implementation of the above strategy in BEngTech (Civil) program is in the early stages and given the nature of the course (final year, specialised project) and relatively small cohort size, collecting quantitative data on student feedback and analysis of the trends were not feasible. Therefore, future work in terms of implementing the approach in few consecutive years and observing the trends is needed. Further research in this area is in progress. However, qualitative feedback from some current students and recent graduates have been very positive, acknowledging and appreciating the real world outcomes and industry connections and relevance. For example, below is the comment from one of the recent graduates whose project led to a conference presentation and publication:

"It was the first real conference I had ever attended and while it was a bit nerve-wracking presenting, I came back having learned a whole lot. I encourage anyone undertaking a research project for their BEngTech to strive for excellence, with the aim to get your work published and attend a conference to present the findings. It was hugely rewarding for me and counts towards professional recognition with IPENZ".

Conclusions

Research and Development is an integral part of the modern industry; therefore, expansion of research in undergraduate level including the Polytechnic education is essential to ensure innovation and relevance to future job market. The traditional strong industry links in Polytechnics through both lecturers and students provide a great opportunity to engage the students in industry-sponsored research projects in particular short-term applied research. Focusing on this strength, since 2015, in the BEngTech program (Civil) in the Ara Polytechnic, research elements are gradually integrated in the process and assessment items of MG7101 course (Engineering Development Project). This resulted in a significant improvement in the quality of outcomes and level of industry engagement. For the first time in the BEngTech program (Civil) at Ara, a number of quality assured publications emerged from student projects. This experience has also been appreciated by the students and industry partners involved in the projects as evidenced by the positive comments and the sustained support from industry through various projects.

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Integrated Engineering may be necessary, but perhaps design would be taken more seriously

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SESSION

S1: Is Integrated Engineering Education Necessary?

CONTEXT

Integrated Engineering (IE) units have been introduced in engineering programs to address the practice-based aspects of engineering including the development of professional skills, such as communication and team work. At one large university in Australia, IE is expected to teach content perceived as non-engineering or not directly relevant to the technical aspects of engineering which includes written communication skills, ethics and recently introduced graduate attributes, such as cultural competence and interdisciplinarity. Feedback from tutors and students is that IE is not directly relevant to their studies. The perceptions and feedback has prompted questions as is whether IE is the only unit to develop these skills, whether they could be developed elsewhere in the curriculum, and what is it about developing these skills, particularly cultural competence, that is resisted.

PURPOSE

The aim therefore is to review the literature to understand how the skills could be embedded within engineering curricula to help determine whether IE is indeed necessary. The focus is on cultural competence as it appears more challenging than other skill areas to incorporate.

APPROACH

A literature review was conducted and involved identifying conceptions of cultural competence, engineering, and design. The review was expanded beyond engineering to include education, business ethics, social psychology to better understand the concepts identified.

RESULTS

The results of the review are that curriculum influences learning and what is valued or what is interpreted as relevant. Adding IE to a conventional curriculum may not achieve the desired outcome of learning for IE given the overall emphasis on what is learnt and how. Design subjects are better able to address socially oriented skill development and provide context for learning. Contemporary broader design approaches are particularly relevant in addressing cultural competence because of a focus on care ethics, inclusiveness, different values, and power relationships underpinning collaboration.

CONCLUSIONS

For concepts of IE to be effective they should be embedded within a range of units across a curriculum rather than concentrated in a few. This can be achieved with a broader and more integrated curriculum and with a focus on design. A broader approach particularly in relation to design allows for understanding of different ways of approaching a problem thus providing better understanding of interdisciplinary and culturally diverse approaches, as well as differences in what is valued.

KEYWORDS

Integrated engineering, cultural competence, design, professional skills, inclusion

Introduction

A number of papers and statements from a range of sources highlight the increasingly complex nature of society, of the need to be more inclusive, and consequently of the need to educate students more broadly particularly in the area of entrepreneurial and professional skills (for instance, Office of the Chief Scientist, 2013; UNESCO, 2010). These have been accompanied by calls to improve engineering education particularly to improve completion rates, attract diverse students, and better prepare students for engineering practice (Maciejewski, et. al., 2017). In part, and to address apparent deficiencies, engineering curricula included professional skill development in units such as Integrated Engineering. Nonetheless, with emphasis on foundational maths and science concepts and the core disciplinary subjects, there are consequences for the value or status of a more socially oriented unit like Integrated Engineering in engineering curricula, and therefore, to student skill development in this area.

The benefits of Integrated Engineering (IE) are in addressing employers' demands for better communication and interpersonal skills, highlighting to students the expectations of engineering practice, as well as aligning with the generic graduate attributes described by universities. The graduate attributes of Australian universities increasingly reflect wider societal influences and industry requirements becoming more inclusive and aware of the employment landscape with its focus on innovation in driving competitiveness. Consequently, university programs are required to embed, in addition to the usual communication skills, skills such as cultural competence or intercultural communication, innovative thinking and interdisciplinarity.

This paper argues that the aims of Integrated Engineering as a vehicle for professional development are better achieved when embedded in contextualised learning experiences relevant to contemporary engineering practice and when students are given multiple opportunities to practice. This is consistent with current engineering education innovations stipulating a more holistic integrated curriculum overall to ensure relevance and preparation for engineering practice (Maciejewski, et. al., 2017). If engineering is equivalent to design in the sense of addressing problems or presenting solutions using a design methodology, then developing professional skills in an authentic design context that also requires technical knowledge would be a more relevant and engaging learning experience as opposed to separating professional skill development from context. Furthermore, design has the potential to develop broader and inclusive graduate attributes such as cultural competence.

In addressing the question about whether IE is necessary, this paper takes a multipronged approach to identify synergies in briefly reviewing engineering, engineering curriculum, design and cultural competence concepts. Firstly, a background to IE is provided.

Background to Integrated Engineering

Integrated Engineering units were introduced in the 1980s in North America when it was recognised that students required non-technical skills and skills to connect maths and science concepts with engineering practice (Froyd & Ohland, 2005). A study by ABET (2006) revealed that requiring professional skills in the outcomes of HE engineering programs had a positive influence on the work readiness of graduates. Similar outcomes were introduced by other accrediting bodies, such as Engineers Australia. The curriculum of IE varies across institutions. Despite the name, IE is likely to be added-on to an engineering program rather than content and skill development being allocated to a range of units. It is typically not embedded within other areas of the curriculum. There is a perception that IE skills could only be taught in a dedicated unit, separate from other contexts of engineering learning. However, as experts in their field and as role models, teaching staff influence the behaviour and attitudes of students (Danielak, Gupta, & Elby, 2014) to the extent that, for instance, students are likely to follow the communication practices of teaching staff without direct teaching. To better understand IE, it is worthwhile investigating the nature of engineering.

What is engineering?

Engineering is commonly described as design (Elliot, 2010; Lavelle, 2015) which involves a process to create an artefact and the design of the artefact itself (Petersen, Nyce, & Lutzhoft, 2015). It is described as a problem solving activity (Engineers Australia, 2016), as well as a practical endeavour, in contrast to science which is more theoretical or laboratory based (McCarthy, 2010). Less common descriptions of engineering are that it is a 'social process' (McCarthy, 2012, p.103) or a 'social-technical process' (Lavelle, 2015, p. 268) which means that engineers work with people, machines and environments (Baxter & Sommerville, 2011). Describing engineering as design is contested since, as Davis (2015) argues, it obscures the many other activities of engineers. In contrast, Turnbull, (2010) argues that design is a core activity. Some suggest that engineering is not well understood and/or is understood differently in engineering faculties (Male & King, 2014; Murphy, Chance & Conlon, 2015). Due to the broad nature of activities, engineering is consequently construed as a complex activity (Grimson & Murphy, 2015). For instance, engineering design is complex as engineers need to determine priorities, such as financial, safety, sustainability, performance, and weigh these against values, such as utility, ethics, aesthetics and social considerations (Turnbull, 2010).

HE curriculum

HE engineering programs are described as hard (Winberg, Winberg, Jacobs, Garraway, & Engel-Hills, 2016). Typically, the first and second year units focus on sciences and maths, and engineering theory is taught prior to practice (Male & King, 2014). Male and King (2014) conclude that this makes engineering difficult and less motivating, particularly since learning is not contextualised. This also means the focus is less on the socio-technical aspects of engineering practice, and may therefore appeal more to a narrower range of students (Danielak, Gupta, & Elby, 2014). Furthermore, this may contribute to engineering identities that are inconsistent with engineering practice (Male & King, 2014), and reflect employer dissatisfaction with the interpersonal, communication and leadership skills of graduates (Graduate Career Survey, 2015). HE institutions are encouraged by accrediting bodies to address these aspects of professional development in a program that includes work experience (Engineers Australia, 2008). How these are addressed, whether added on or embedded, is an issue. Mulder (2017) claims that adding on elements to existing programs or units of study (such as, IE) is insufficient. Godfrey and King (2011) doubt this issue considered since there is an expectation that students adapt to faculty culture and programs.

Engineering programs in general consist of independent discipline areas, where maths, for instance may be taught by a different discipline, such as science. The onus is on students to identify how different subject areas connect (Maciejewski, et. al., 2017). On the other hand, an integrated curriculum focuses on creating learning experiences to ensure different disciplinary areas are connected which adds meaning and relevance to the program of study (Fincher, 2016). Fincher (2016) reports that where the curriculum is integrated students tend to better understand and retain subject matter, as well as increase their critical thinking abilities. The curriculum influences learning and engagement. For instance, research has found that females and minority groups are particularly attracted to what is referred to as 'socially engaged engineering' (SEE) which covers environmental or humanitarian engineering (Litchfield & Javernick-Will, 2015, p.394). Common elements of these programs are to enhance understanding of contextual constraints, including legal and economic, meet the needs of the local people, and address sustainable use of available tools (Mũnoz & Mitcham, 2012).

Litchfield and Javernick-Will (2015) claim that individuals who are attracted to SEE have "broader interests and motivations than other engineers" (p. 411), and are more open to experiences and driven to do good. However, the findings are that these interests and motivations may be negatively impacted by the curriculum. For instance, a longitudinal study of 326 engineering students at four HE institutions in the US found that students' social interests declined over the period of their undergraduate program (Cech, 2014). Cech (2014) claims this is due to what is valued in the curriculum. For instance, if students perceived that there was weak emphasis on ethics and social issues, this then correlated with a reduction in social interests. Rulifson and Bielefeldt (2015) report similar findings in their study of 32 engineering students from seven institutions interviewed twice, once at the end of their second semester and then again at the end of their fourth semester. The conclusion is that through the curriculum students are taught to value decisions that preserve the rational scientific aspects of engineering, and consequently, the science and technology aspects are accorded higher values than social, environmental and ethical ones (Cech, 2014). What is valued by a faculty as evidenced in the curriculum influences what students' value.

These findings have implications for initiatives to broaden the appeal of engineering with the goal to improve innovation and thus competitiveness (Office of the Chief Scientist, 2013; OECD, 2015). It complicates the already challenging task of attracting and retaining a more diverse cohort (Eris et al., 2010; Meyers & Marx, 2014). Some of the challenges may be due to conflicting messages about the nature of engineering and who does it. This is evident in the contrast between K-12 engineering programs (i.e. those in school settings) and those in HE (Lachney & Nieusma, 2015). Lachney and Nieusma (2015) argue that K-12 engineering programs embrace inclusive and engaging design-centred activities, while those in HE promote the maths and sciences or 'fundamentals-first pedagogy' (p. 26) in the first years. They also argue that a fundamentals-first pedagogy promotes exclusiveness in preferencing a more limited technical and analytical learning over creative problem solving, with consequences for individuals' personalities, values and emotions in developing an engineering identity.

There is general agreement amongst scholars of SEE that students should be taught systems thinking (Malkki & Paatero, 2012) or more holistic thinking (Lozano, 2010) that incorporates trans- or multi-disciplinary perspectives. This is not confined to SEE. There are calls elsewhere for curricula to implement a holistic framework or ecosystem to better understand complexity and to use systems thinking (Bloom, 2012; Rawlings-Sanaei, 2016). In relation to SEE, the goal is to integrate or embed it within the curriculum (Lozano, 2010; Malkki & Paatero, 2012), rather than adding it on to existing curricula (Mulder, 2017). Mulder (2017) proposes a curriculum that addresses how engineering knowledge could contribute to sustainable development rather than on the foundational elements of engineering or the discipline per se. This kind of objective requires clarity on the role of engineering in today's society and it would encourage a focus on design. The development of systems engineering enabled engineering programs to place more focus on design and less on foundation first pedagogy (Grimson, 2015). A focus on design aligns with project based learning approaches which are interdisciplinary and encourages engagement with context (Grimson, 2015). The principles underpinning systems are similar to those of sustainability as both consider holistic thinking in addressing problems (Elliot & Deasley, 2007). In sum engineering is complex and HE programs influence learning with consequences for what is valued. An integrated curriculum that highlights design and uses systems thinking has the potential to promote a broader approach.

Engineering Design

Design in engineering is generally associated with project-based work (Leigh, Goldfinch, Prpic, Dawes, Kennedy, & McCarthy, 2014), and requires synthesis of core and specialised engineering knowledge (Winberg, Winberg, Jacobs, Garraway, & Engel-Hills, 2016). The outcome of design is generally assessed according to its usefulness and how well it complies with standards and other constraints. However, some believe this is a restrictive approach to design since usefulness might be determined in a narrow way, for instance, from a technical point of view without consideration of a wider social and environment context (Cech, 2014). Determining what the context is (Grimson, 2015) or what is included in a system is challenging or contested (Davis, Challenger, Jayewardene, & Clegg, 2014), since as Cech

(2014) claims, contexts can be designed out of or excluded from the problem concept. This is acknowledged in the literature with calls for a change in thinking to address global challenges (Catalano, 2014; Elliot & Deasley, 2007).

Petersen, Nyce, & Lutzhoft (2015) claim that a restrictive design context inhibits engineers from developing an understanding of human behaviour. Murphy (2016) suggests this is because technology rather than human beings is foregrounded. In recognition of this weakness, engineering design methodology has undergone change since the latter half of the 20th century (Vermaas, 2015). Nonetheless design in engineering is still considered a rational, problem solving exercise with the assumption that by selecting alternative designs, the design problem is solved (Richter & Allert, 2013). The choice selected and evaluation of the design's usefulness is dependent upon the knowledge framework or epistemology of the designer or design team. Thus for instance an engineering solution to a problem would typically involve technology.

One design method that has gained popularity this decade is 'Design Thinking' (Brown, 2009). Design Thinking has broadened the roles and responsibilities around *who* can design placing non-engineers (such as psychologists, or anthropologists) in design roles (Vermaas, 2015). Murphy (2016) proposes that Design Thinking has gained popularity due to techniques to solve complex problems because of its broader sphere of influence and inclusive approach. For instance, "…people, practices, objects, materiality, forms, ideologies, consumption, politics, etc are all afforded attention without having to promote or demote any one of them" (Murphy, 2016, p. 443). In addition, the focus is on the design process and the creative and contextual nature of design (Richter & Allert, 2013). The promotion of this design approach implies that engineering design methods are limited in solving complex problems.

Other inclusive and contextual approaches are evident in range of projects reported in the literature, such as a future car design project which takes into account how a range of people would use the car, including people with disabilities, seniors, children (Kunur et al., 2016). The team working on this project includes engineers, designers, ethnographers. Another project with an inclusive focus is technology for the ageing (Giaccardi, Kuijer & Neven, 2017). Giaccardi, Kuijer & Neven (2017) are critical of technological innovations that produce solutions for single, narrow scenarios based on stereotypes of elderly people. They claim this is due to the problem solving methodological approach of technical design. For instance, instead of seeing ageing as a problem to be solved, another perspective is to see the elderly with different skills and abilities which can be used in creative ways to adapt technologies beyond single use or one function. The orientation to design is more positive. Similarly, Ambole, Swilling, M'Rithaa (2016) argue that design needs to be more than a technological product to address a wider concern with social agency, focus on process, and complex social situations. Rather than a prescriptive design methodology and problem-solving approach, an approach that combines the more descriptive ethnographic framework provides a more holistic concept of the social context. In their case, it was to improve informal sanitation in a settlement in South Africa.

In the cases described, designers and ethnographers collaborate with potential users, who could be considered co-collaborators or participants since they play a role in the design. In these cases, design has broadened to consider consequences rather than just the form of design and the action to produce a design. Consequences arise because design has both direct and indirect impacts on human lives, and therefore has moral implications (Murphy, 2016). Overall this has led to movements that focus on empowerment and sustainability, such as 'Design for Social Change' (Shea, 2012) and 'Design Anthropology' (Otto & Smith, 2013). The wider notion of design with the focus on consequence and empowerment is more compatible with social justice goals articulated in understandings of Cultural Competence (discussed in the following section). As the above examples illustrate, looking at design challenges from different perspectives allows for inclusiveness, but there is also acknowledgement that solutions/products exist within systems and thus less emphasis on one-off product development.

Not all design approaches are equal, for instance, while Design Thinking has been promoted to address innovation in developing countries (Capel, 2014), it has been criticised for promoting or imposing Western design values (Nichols, 2015). Furthermore, critics have linked it to an innovation agenda which is set by global organisations, such as the OECD and World Bank (Capel, 2014; Tunstall, 2013), raising questions about who benefits, and what innovation means for Indigenous and other communities around the world. A recent approach countering this issue is 'Transition Design' (Irwin, Kossoff, & Tonkinwise, 2015). A particularly Australian perspective is 'Indigenous Engineering' (Leigh, Goldfinch, Prpic, Dawes, Kennedy, & McCarthy, 2014) which acknowledges that there are First Australian (Aboriginal and Torres Strait Islanders) and Western worldviews where knowledge is shared and negotiated rather than preference given to one worldview.

Such an approach requires a recognition of different values rather than just Western value systems which Tunstall (2013) argues can undermine the wellbeing of particular groups, as well as their environments. To ensure other value systems can be addressed, broader design approaches propose a design methodology that includes inclusiveness, collaboration, respect for people's values, recognition of politics or power relations and ethics (Capel, 2014; Irwin, Kossoff, & Tonkinwise, 2015). This broader concept of design includes values or axiology. Lincoln and Guba (2000) argue that axiology has been designed out of science to maintain objectivity, leading to claims that science is not concerned with notions of goodness (Goodyear, 2015). Science, and by implication engineering's, reductive approach, simplifies conceptions of the world since what is promoted is a single worldview (Lincoln & Guba, 2000). This then has consequences for what is valued. The higher status of science within Western societies means that its worldview or ideology is dominant thus overriding other worldviews (or value systems) (Lincoln & Guba, 2000). However, solving complex problems requires more than a single worldview and therefore design needs to allow for multiple values and worldviews. It is at this point where the notion of Cultural Competence can be discussed.

Cultural Competence

Incorporating cultural competence (CC) into Australian HE programs was initiated by the Bradley Review (Bradley, Noonan, Nugent, & Scales, 2008), and followed up by reports by Universities Australia (2011a & b). These highlight a history of initiatives to improve the educational outcomes of First Australians, and propose that continuous marginalisation has been a factor in the failure of many of these initiatives. The current situation is that First Australians experience considerable disadvantage in comparison to Later Australians. Disadvantage is, '…any barrier that hinders equity of participation and success in education and labour markets' (Polvere & Lim, 2015. p. 33). CC is designed to improve access to, retention and inclusiveness in, educational programs. The other purpose is to ensure students are aware of the disadvantage experienced by certain groups in society and contribute to improving the social and economic outcomes of these groups thus providing benefit to society generally (Universities Australia, 2011a). Therefore, HE has a significant role in addressing equity and social justice issues. CC is defined by the National Centre for Cultural Competence (2016, para. 3) as:

> *…the ability to participate ethically and effectively in personal and professional intercultural settings. It requires being aware of one's own cultural values and world view and their implications for making respectful, reflective and reasoned choices, including the capacity to imagine and collaborate across cultural boundaries. Cultural competence is, ultimately, about valuing diversity for the richness and creativity it brings to society.*

There has been robust discussion about the definition of culture (Azzopardi & McNeill, 2016; Collins & Arthur, 2010; Wear, Kumagai, Varley, & Zarconi, 2012). One problem with the term 'culture' is the connotation of fixed characteristics of specific ethnic and racial groups;

typically, these are the superficial or explicit characteristics associated with food, dress and behaviours, amongst others (Morris, 2013). This can generate stereotyping and associated assumptions which may form the foundation for racism (Grote, 2008). Dick, et al. (2006) argue that individuals are more than their culture because their behavior, actions and beliefs are influenced by many other characteristics including gender, sexuality, geography, socio-political and economic contexts. Consequently, researchers have suggested other terms such as ‘diversity competence’ (Chun & Evans, 2016) and ‘critical consciousness’ (Staub, 2015). The aim is to focus on the complexity of individuals and acceptance of their multiple characteristics rather than on one aspect, such as culture, which can lead to bias and stereotyping.

Dick et al. (2006, para. 30) also suggest recognising the role of power and privilege in understanding the identity of individuals which some argue is at the core of understanding disadvantage (Chun & Evans, 2016). Power could be interpreted as the restriction of choices that one group imposes onto another leading to disadvantage (Nakata, 2007). It is now generally agreed that culture is dynamic rather than static, and involves more than just different ethnicities and races (Azzopardi & McNeill, 2016; Collins & Arthur, 2010; Wear, Kumagai, Varley, & Zarconi, 2012). A similar shift is reflected in current multicultural and cross-cultural literature where culture is now usually interpreted from a critical perspective, such as via understandings of power in society (Chun & Evans, 2016).

From the definition of CC and with a broader understanding of culture, it is possible to identify similar characteristics with broader, holistic design approaches that incorporate values, respect, and ethics. Furthermore, such design approaches are more inclusive and allow for collaboration with individuals and communities as well as acknowledge context, including social, political, economic, cultural elements that individuals and communities involved represent. Given these factors, there is then common ground between CC and design. Here design is *with* rather than *for* which shifts the focus from imposing a design to collaborating in design processes and the learning that entails. Design is acknowledged to shape the future as a consequence of interactions with others and the natural world (Balsamo, 2011; Van Der Velden, 2014), or the way it changes the environment and the ways people interact with it (Love, 2007). Thus, design influences quality of life. Individuals and communities need a say in their quality of life. Incorporating the values of others in design and engineering is therefore important.

IE or design?

While IE curriculum is dependent on the institution or faculty, it is associated with a perception, historically influenced, that it is about professional skills development. Current attempts to modify this perception, whether intentional or otherwise, is with a change in name, for instance, Systems Design (Buskes, 2014) and the use of project based learning. The main problem with some iterations of IE is also a problem of the whole engineering curriculum. Subject matter is segregated and not contextualised. However, learning is contextual. Learning requires language, and that language and the way the information is communicated is done in conjunction with content. It is not possible to separate learning to communicate or work in engineering contexts from engineering itself. As noted in the academic literacy domain, learning, content and communicating are tightly linked (Chanock, 2007; Devereux & Wilson, 2008), and thus that communication skills are best embedded in the context specific disciplinary domain (Arkoudis, 2014). From this position, embedding professional and other skill development within an engineering learning context is a more effective teaching and learning practice. Furthermore, without contextual or authentic experiential learning, skill development tends to be abstract from engineering practice. If that is the case, then students struggle to see its relevance. Another problem is that if there is little emphasis on profession skill development then these are likely to be perceived as having less value or importance particularly when the curriculum emphasizes analytical over creative learning.

Design, particularly, the broad design approaches allow for a range of skill development possibilities. While fundamentals-first pedagogy may take priority in engineering education, evidence shows that early and consistent participation in engineering design results in improved learning outcomes for the professional skills, such as, communication, teamwork, innovative and critical thinking (Kusan, 2014). With a broader design approach, acknowledging additional contextual elements, such as ethics, values, politics, diversity, will contribute to the development of broader professional skills. In addition, broader design is interdisciplinary and together with cultural competence address inclusiveness. A broader context allows for students to develop better understanding in working with a wide range of stakeholders and designing for consequences for these stakeholders. This might involve considering if a technological solution is warranted and examining in collaboration with others what really needs to be achieved acknowledging the social, ethical and environmental dimensions of particular issues.

A broad design approach is likely to appeal to a greater range of students providing diversity in values and ideas, and thus developing the ability to work in diverse groups. Employers are increasingly emphasising the importance of professional skills particularly cultural competence, teamwork, and innovative thinking. Research shows that diversity is beneficial to innovation and thus competitiveness, and that diverse organisations have significantly better financial returns (Deloitte, 2015; McKinsey, 2015). Organisations will therefore try to identify graduates that can contribute to innovation in collaboration with diverse work colleagues.

Conclusion

By articulating understandings of engineering, design approaches and CC, synergies have been identified that provide options in addressing the development of broader professional skills and of the need to be inclusive. Applying knowledge and skills within a context of practice involving design and project-based learning provides experiential learning. Design is a core element of engineering, and it is therefore necessarily integrated. Within a curriculum, design has the potential to resemble modern engineering practice which is interdisciplinary, highly competitive, involves cross-cultural contexts, diverse clients and needs, and requires innovative thinking. However, to be effective a broad design approach should be integrated across the curriculum enabling practice. This would also help ensure that it is valued and has relevance. The answer as to whether IE is necessary is not straightforward primarily due to historical factors about how to teach engineering. These factors may prevent a forward-looking engineering program from meeting the complexity of global challenges and from engineers taking leadership in addressing these. In sum, this paper concludes that a broad design approach is more appropriate as a pedagogical tool than IE.

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Enhancing Technical Writing Skills for Undergraduate Engineering Students

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Context

Effective technical writing is an essential skill for professional engineers. Graduate engineers spend 30–40% of their day writing, and professional engineering organisations consistently list communication as a key graduate competency. At the same time, technical writing is one of the least developed technical skills in engineering undergraduate programs. This paper discusses the initiatives and outcomes of a pilot program in the School of Chemical Engineering at The University of Queensland (UQ) designed to enhance the technical writing skills of engineering students.

Purpose

The aim of this pilot study is to enhance the technical writing skills of engineering students by embedding an integrated and progressive technical writing program in core undergraduate engineering courses.

Approach

In this pilot study, a multi-disciplinary team comprising academics from the School of Chemical Engineering and the School of Communication and Arts at UQ collaborated to develop, deliver, and evaluate a series of new writing lectures and workshops embedded in core chemical engineering courses. The content of these materials was informed by a literature review of best practice in engineering writing programs, a survey of Australian industry, and a curation of e-resources including the UQ Massive Open Online Course (MOOC) on writing and grammar.

Results

Early results from the pilot program are promising. We found that most students valued the technical writing support and they were able to incorporate feedback from teachers to improve the quality of their written assessments. The pilot study also highlighted the challenges of implementing program-wide changes to the established curriculum, including engaging students' attention in technical writing workshops and obtaining the support of other academics.

Conclusions

Early results from this work show that is possible to enhance the writing skills of undergraduate engineering students by embedding active learning activities in their core engineering courses. Future work in this project will investigate how to expand the reach of technical writing activities across the School of Chemical Engineering and across the Engineering Faculty.

Keywords

Technical writing, engineering education

Introduction

Effective technical writing is an essential skill for professional engineers. Most engineers spend a significant part of their day writing (Trevelyan & Tilli, 2008) and engineers who write well are more likely to be promoted (American Society of Mechanical Engineers, 2011). In the report *Visions of Engineering in the New Century: The engineer of 2020* (2004), the National Academy of Engineering states: “As always, good engineering will require good communication”.

Many Australian-based engineering companies regard communication skills as increasingly important because of increased specialisation and the trend towards global outsourcing of engineering functions (Beer & McMurrey, 2014; University of Adelaide, 2009).

For these reasons, engineering educators have a responsibility to ensure that students learn writing skills alongside the technical skills of their discipline. Entry-level employees and graduates will face a constant and complex array of writing tasks, so they need to be able to confidently articulate technical ideas in compelling, logical, coherent, and economical prose (Petelin, 2016).

In Australia, the integration of writing skills into engineering curriculums is recognized as important, but rare in practice (McGregor et al., 2000). With both limited resources and limited scope to expand the content taught in existing engineering courses, we set out to obtain evidence about the current state of graduate writing skills, how these skills are meeting industry expectations, and what opportunities exist to enhance the competence, employability, and reputation of engineering students

To this end, a multi-disciplinary team comprising academics from the Schools of Chemical Engineering and Communication and Arts undertook a pilot project to embed technical writing into existing core courses. The key deliverable of the project to date has been a set of technical writing lectures and active-learning tutorial activities designed around best practice in teaching technical writing in engineering faculties, the perspective of Australian industry, and elements of WRITE101x English Grammar and Style, a MOOC (massive open online course) on writing and grammar.

The project was funded by a Strategic Teaching and Learning grant offered by the UQ Faculty of Engineering, Architecture and Information Technology (EAIT).

This paper discusses the methods and early findings of this pilot project of the School of Chemical Engineering at The University of Queensland.

Review of the literature

Industry views

There have been calls to embed writing instruction into engineering courses in Australian universities for more than 20 years. In 1996, the Institution of Engineers Australia (IEAust, now Engineers Australia) commissioned a national review of engineering education, which ultimately resulted in new standards that included “effective oral and written communication” as one of 10 generic competencies required by a “professional engineer graduate” (Engineers Australia, 2013).

Recent surveys show that Australian employers still identify written and oral communication skills as a critical competency when recruiting engineering graduates. One 2013 survey found that communication skills were the criterion most important to these employers (Graduate Careers Australia, 2014).

Similarly, recent studies commissioned by professional engineering bodies confirmed that skills in written and oral communication and in creative and critical thinking (sometimes referred to as ‘soft skills’) are necessary to be a competent engineer, but were not being adequately taught in engineering degrees (Lattuca et al. 2006; Lee 2003). In response, industry professional bodies have developed new standards reflecting the skills required by what Ardington (2011) has called the 'three-dimensional' engineer.

Technical–writing education frameworks

Engineering educators have adopted (and adapted) various frameworks drawn from writing pedagogy and other areas of educational theory. Writing in 1995, Robinson and Blair note that frameworks for teaching writing can be grouped into three main categories:

- writer-oriented composition ("the concentration on the process of writing, including prewriting activities, drafting, editing and rewriting")
- genre-oriented composition ("analysing examples of good and bad texts [from a particular genre] and incorporating the good features into one's own writing")
- reader-oriented composition ("the writer must know, understand and write for the reader").

Our pilot project has used elements of all three frameworks.

The University of Adelaide, which integrates the teaching of writing and teamwork skills throughout its engineering degree, adopts a "democratic and student-centred approach" (Missingham & Matthews, 2014). Yalvac et al. (2007) concur, endorsing instruction that is "learner-centred" and "community-centred". The University of Adelaide also uses what it calls a "spiral curriculum", based on the work of Jerome Bruner, who argued that a curriculum "should revisit the basic ideas repeatedly, building successively until the student has grasped the full formal apparatus that goes with them" (1960). We understand the value of a spiral curriculum and have implemented follow-up sessions on writing in our project.

We have also taken on board a critical thinking framework. As Bean says, "writing is both a process of doing critical thinking and a product communicating the results of critical thinking" (Bean 2001, quoted in Damron & High 2008). Damron and High (2008) use "a model of critical thinking to structure writing assignments" for first-year engineering students.

Yalvac et al. (2007) also apply a critical thinking framework to teach writing to later-year engineering students, seeking to improve "student performance in difficult writing skills such as argumentation and synthesis". Critical thinking and effective writing are closely intertwined. We recognised in our lectures and workshops that understanding and practising critical thinking is crucial to the process of effective writing.

Different writing skills—generic, academic, and discipline-specific

Generic writing skills are writing competencies that are useful to any writer in any situation. These generic skills include mechanical aspects of writing such as spelling, punctuation, and grammar (Ardington, 2011; Fernandes, 2012; Lord, 2013), but also higher-order skills such as writing clearly and concisely, structuring paragraphs and documents in a logical fashion, and formulating persuasive arguments (Manion & Adams, 2005; Robinson & Blair, 1995).

Academic writing skills are those required to successfully write academic assignments (such as essays). Learning the conventions of academic writing presents one of the greatest challenges for many first-year university students, including many engineering students (Horstmanshof & Brownie, 2013; Skinner & Mort, 2009; Wilkes et al., 2015; Wischgoll, 2016).

Academic writing skills include approaches to content and structure that reflect the expectations of an academic audience (Wischgoll, 2016). Library research and referencing are also key (Horstmanshof & Brownie, 2013). But, to be a competent academic writer, students must also be able to construct a convincing argument and understand the context in which they are writing.

Discipline-specific writing skills in this case are those required by engineers. To acquire these skills, students need to know the different types of documents written by professional engineers; understand the purpose, content, and structure of those documents; and practise writing them (Boyd & Hassett, 2000; Felder & Brent, 2003; Robinson & Blair, 1995; Trevelyan, 2010). They include technical memos, reports, proposals, and specifications.

In addition, students must learn the writing *style* used in engineering documents. Walker (1999) refers to the "engineering persona", and argues that it is linked to stylistic choices such as when to use the passive voice and how much to explain key terms and concepts. Only by using such stylistic features appropriately, she says, will students convey an "experienced engineering persona, one that will be accepted". This is essential if graduates are to meet professional expectations and fit in with their peers when they join the workforce.

Best practice for teaching writing skills to engineering students

The literature concludes that the best way to embed writing within an engineering course is to base it around problem-solving projects directly relevant to engineering problems (rather than teaching 'theoretical' writing skills). This approach allows students to apply and integrate knowledge and techniques learned across their course to a realistic problem, developing creative skills, formulating problem statements and specifications, solving open-ended problems, considering alternative solutions, determining feasibility considerations, and evaluating realistic constraints. Using assignments that include problem-solving provides an opportunity to show how solutions to problems should be presented as fully developed and carefully written reports, not as lists of calculations. Allocating marks for the writing component within assignments will also help ensure students engage with the material and see it as 'need to know' for their academic success.

Best practice in assessing and giving feedback on students' writing (which we have followed) advocates the following:

- Writing assignments should relate to course content and resemble the writing done by professional engineers.
- However, personal 'reflective' writing assignments also benefit students.
- Shorter writing assignments benefit both students and staff.
- Effective and timely feedback on writing tasks is critical to improving students' writing skills.
- Engineering staff should receive training in how to provide effective feedback on writing.
- Good rubrics are important, and teaching to a rubric can deliver good results.

Methodology

The key initiatives of this pilot project included:

- conducting a literature review to identify best practice in the teaching of technical writing to undergraduate engineering students
- surveying Australian engineering employers to obtain more evidence about where employers feel new graduate writing skills are lacking
- developing and delivering technical writing materials for core, compulsory courses
- evaluating the benefits of the program through ongoing student feedback.

Industry survey

We distributed an online survey to 55 Australian engineering employers from around Australia in September 2016. The companies were asked a series of questions relating to how valuable these employers regard writing ability when employing graduate engineers.

Twenty-nine survey responses were received. Of these respondents, 60% worked in a large engineering consulting firm with more than 100 employees, 28% in a smaller firm of fewer than 100 employees. The remainder of the respondents were from state government, local government, and academia. Within these organisations, 39% of respondents were in a management position and 46% were in a technical position. 71% of respondents had supervised UQ engineering graduates.

Our industry survey confirmed that effective writing skills are highly valued by engineering employers in Australia. As a broad summary:

- 88% of respondents view technical writing skills of graduate engineers as either vital (60%) or important (28%).
- 58% see the primary importance of writing training as the reduced need for multiple revisions of works.
- 85% of respondents fully support integrating writing components into the engineering curriculum.

Respondents were asked to nominate the top five writing-specific issues that make documents in their organisation difficult or frustrating to read. The major issues highlighted were:

- inability to highlight or identify critical information
- lack of clarity
- wordiness
- inability to summarise
- weak connections between words and data
- poor organisation
- incorrect grammar and convoluted syntax.

Respondents made the following comments about the writing skills of engineering graduates in particular:

- Verbose and indirect writing is very common among graduates.
- Graduates need to develop skills in writing in a range of engineering formats including emails, letters and memos, progress reports, summaries, and PowerPoint slides
- Interpretation of technical data and succinct summaries are key needs for graduates.

Approximately 33% of respondents offer in-house writing training to their staff, 25% employ external consultants to deliver writing training, and 8% use Engineers Australia's writing training courses. 55% would still offer in-house writing training to staff even if writing is incorporated into the engineering curriculum.

> *In general, engineers are not able to submit technical information directly to clients until they are at a senior level about five years after graduation. (survey respondent)*
>
> *Writing skills and good project management skills go hand-in-hand. This is important because it shows systematic thinking about a project. Systematic thinking and good technical writing cannot be separated. (survey respondent)*

Delivery of lectures and workshops

The key aims of this pilot writing program were to raise student awareness of the importance of writing clearly and to explain the elements of effective technical writing, including conciseness, clarity, accuracy, relevance, and significance. To achieve these aims, and armed with the knowledge gained from the literature review and industry survey, we developed a range of technical writing instructional material specifically designed for the chemical engineering students.

During 2016–2017, this material was delivered to the students in a number of different formats including:

- A one-hour lecture to 200 students in the core second-year, introductory chemical engineering course (CHEE2001 Process Principles). The purpose of the lecture was to highlight the importance of effective writing and to introduce the elements of good writing including knowing your audience, structuring technical reports, writing clear paragraphs, and using plain English.
- A two-hour active-learning workshop for 200 students in CHEE2001. In the workshops, students worked through a series of activities in pairs and groups to practise the writing principles outlined in the lecture. The cohort was divided into two groups of 100 students to allow for more manageable classroom interactions.
- A two-hour active learning workshop for 180 students in the third-year, core chemical engineering course (CHEE3004 Unit Operations), which reinforced and extended the messages of clear writing to include simple sentence construction, pitfalls of nominalisation, the use of the active voice, and simple word selection. Once again, the cohort was divided.
- In-class and written feedback from CHEE2001 was provided by academic staff on the quality of the students' executive summaries for the first of two project technical reports.
- A bank of accessible writing resources was provided for the students via the course Blackboard sites, including a guide to writing a technical report, examples of good executive summaries, and recommended texts on technical writing.

Findings

Writing lectures and workshops

The pilot study produced three main findings. Firstly, we found that most students do value technical writing support and can improve their writing skills with direct writing tuition, teacher feedback, and access to relevant writing references. Secondly, the collaboration of academic staff from different disciplines across the university was effective in developing and delivering useful writing resources for our students. Finally, it was clear that persistence and creativity are required to engage students and staff in program-wide changes to the established curriculum for non-core activities. In the following section, we elaborate on these findings and provide some examples of our students' responses.

Students value writing support and do respond to tuition

The need for, and value of, technical writing support for our undergraduate chemical engineering students is clear. Evidence includes:

- Many of the students' written assessment submissions, especially those in the early years of the degree, are not at an acceptable, industry-ready standard. Common issues with students' reports include poor overall structure, convoluted sentence construction, poor structuring of argument, buried findings and recommendations, and poor regard for the audience of the report.

- Students themselves reflect that that they feel daunted by the prospect of writing technical reports. During a writing workshop, we asked the students to reflect on how they felt when they sat down to write for their university assessment. The responses were uniformly negative, with typical responses of ‘upset’, ‘lethargic’, ‘sad’, and ‘depressed’.

Most students appreciated the writing support that they received. When we surveyed the CHEE2001 students after the writing workshops in 2016 and 2017, >80% said that they found value in the lecture and workshops, >90% said that they had implemented some of the new learnings when writing their assessment pieces, and >90% said that they would like to see more technical writing support in other chemical engineering courses. At the same time, we observed a noticeable improvement in the quality of the CHEE2001 reports in the cohorts to which we gave writing instruction and feedback.

Some examples of students’ responses to the writing components were as follows:

> *I know of other students that might not take it as seriously as the actual content of the course, but knowing how to write reports is something I consider to be important. I used to think bigger words, longer sentences = smarter, but I've learned a lot about how to improve my writing.*

> *I would like to really perfect the executive summaries I write. From the feedback I got from my executive summary for Project 1, I seem to be in a position where I am close to being able to consistently write clear, concise and informative summaries of the report.*

Value of cross-discipline collaboration

Every discipline has its own system for looking at and organising experience—a perspective on the world that is reflected in its questions, research methods, and the roles its practitioners play. Writing in every discipline is a form of social behaviour in that discipline, so students need to be socialised into the intellectual conventions of their disciplinary and professional discourse communities (Petelin, 2012).

Our working party consisted of academic staff from two UQ Schools, the School of Chemical Engineering and the School of Communication and Arts. Over the course of the last two years, we met regularly and collaborated to develop and deliver writing tuition specifically tailored for chemical engineering students. We each brought to the team different knowledge and perspectives based on our disciplinary fields and experience and intertwined these different strengths to achieve a better product for our students. We are confident that, with this cross-disciplinary collaboration, we have produced materials of real value to our students.

Challenges of implementing writing tuition across a program

There were several challenges to embedding writing tuition in established, core chemical engineering courses. These included:

- The established engineering curriculum is full. Finding a place to add in additional lectures and assessable writing workshops is difficult. We found that the buy-in from academic staff was most successful when they understood the importance of effective writing in industry and were able to make room in their established curriculum for explicit instruction. In the future, we face the challenge of gaining the acceptance and cooperation of staff who do not share this same appreciation of embedded writing instruction.
- Undergraduate students were less inclined to engage in the writing tutorial activities where there were no marks assigned to the writing activities. While most course coordinators were comfortable in assigning presentation marks for reports, some

were unwilling to change the well-established assessment schedules to support additional writing activities. Once again, buy-in from academic staff was strongest from those who appreciated the value of effective writing in industry.

- Delivering timely, relevant feedback on technical writing is challenging and time-consuming. Engineering academics may not have the necessary skills to give effective writing feedback and some are reluctant to increase their marking times to give this specialist writing feedback. We aim to mitigate this problem by developing and using clear and consistent marking rubrics that reward effective writing.

Conclusions and future research

We feel that, in spite of the challenges of embedding technical writing tuition in core chemical engineering courses, there is value in persisting with this pilot program. Engineering firms highly value strong writing skills in engineering graduates. The students' need for writing support is great and most students can see the value of participating in specialist writing workshops.

To date, the pilot project has produced:

- a permanent and sustainable change to the second-year core chemical engineering curriculum to include a technical writing lecture and workshop
- a small but growing set of technical writing resources that are being shared with other academics in the School of Chemical Engineering and across the wider EAIT Faculty.

There has been encouraging interest in the pilot project from engineering academics in the School of Chemical Engineering and from other UQ engineering Schools. Our plans for maintaining the program also include implementing a student-led peer-writing support program to encourage the practice of effective technical writing skills.

We expect that the future work will continue to embed technical writing components across the School of Chemical Engineering and across the Engineering faculty more broadly, including structuring out-of-classroom materials and resources for students to access and thereby enhance classroom-based learnings.

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Characterising the learning dispositions of first year engineering students

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Introduction

The increased adoption of blended learning designs such as flipped instruction by STEM academics has brought learning benefits for many students; however, it relies heavily on students being able to take much more responsibility for their own learning than in traditional lecture-based subjects (Reidsema et al 2017).

Previous studies (Willey & Gardner 2015, 2014a, 2014b, Gardner et al. 2014, Willey et al. 2014) of students in two different engineering majors at the University of Technology Sydney have shown that students who perform poorly in flipped learning environments typically do not demonstrate the agency and self-efficacy necessary to take responsibility for their own learning and hence have difficulty achieving the cognitive changes expressed as learning outcomes in subjects. Poor self-efficacy, that is a competence belief about one's capability to execute a particular action and achieve a particular goal, has been linked to attrition in previous research:

> *Many different factors underpin attrition decisions in any one institution and for any one individual, for whom attrition usually results from the aggregation of diverse factors rather than 'the straw that broke the camel's back'. The only attrition triggers which span most universities and years of study are lack of clear reasons for being at university or academic self-efficacy (Willcoxson et al 2011)[6].*

Crick and Goldspink (2014) refer to the link between learning dispositions, agency and identity and how students' thinking about these concepts, such as self-efficacy, frames their future learning trajectories. While university programmes generally address knowledge generation, Crick et al (2015) argue that forming a learning identity is also "pedagogically significant".

The research of Thomas (2013) reports that

> *...students often experience stress, uncertainty and use ineffective learning strategies when they are not supported to understand how to direct their own learning... findings suggest that learners can demonstrate increases to cognitive and metacognitive functioning, as well as self-efficacy through engagement with a program to support self-regulated learning...*

However, Thomas (2013) also found that there are "significant challenges to encouraging all students to engage with such a program".

Buckingham Shum and Crick (2012) point out that the development of self-regulation and self-efficacy impacts not just student performance at university but also their performance in the workplace:

> *Theoretical and empirical evidence in the learning sciences substantiates the view that deep engagement in learning is a function of a complex combination of learners' identities, dispositions, values, attitudes and skills. When these are fragile, learners struggle to achieve their potential in conventional assessments, and critically, are not prepared for the novelty and complexity of the challenges they will meet in the workplace, and the many other spheres of life which require personal qualities such as resilience, critical thinking and collaboration skills.*

As more academics adopt blended learning environments in their subjects, these students are at greater risk of not successfully completing their subjects, with a worst case scenario of multiple failures and hence of subsequently dropping out of their course.

Before self-efficacy, agency and other personal characteristics can be developed students need a language to describe these concepts so that they can think about them and talk about them with each other and with their instructors. Conceptual frameworks are useful for guiding data collection and analysis in a research environment, and just as useful in practice for guiding thinking about the various aspects of a phenomenon and the relationships between these aspects. This paper reports how the use of a learning framework, the Crick Learning for Resilient Agency (CLARA) with first year engineering students in two Australian universities has provided us with information about their learning dispositions and given them a language to think about their learning.

Background

The CLARA framework (Learningemergence, 2015) includes eight elements which have been found to contribute to learning ability. These include:

mindful agency: incorporates managing the processes of learning, managing the feelings associated with challenge, and agency in taking responsibility for learning purposes, processes and procedures. It integrates three distinct strands in the research literature: metacognition, the role of affect in self-regulation, and self-efficacy or agency;

sense making: is about making connections between ideas, memories, knowledge, skills, facts and experience – and making meaning of them in relation to each new context of learning and performance;

creativity: is a function of imagination, intuition, risk- taking and playfulness. Playfulness is a way of exploring ideas and testing alternative pathways for problem-solving. It is also instrumental to seeing problems with a 'different lens' which is important in shifting paradigms and worldviews;

curiosity: is about the desire to investigate, find more out and ask questions. A curious learner does not simply accept what they are told without wanting to know for themselves whether and why it's true;

belonging: is about how much a learner feels part of a 'learning community', a group with a shared commitment to learn, improve and do better, whether at school, at work, at home or in the wider community. This learning community provides guidance, support and encouragement in relation to learning;

collaboration: the skills to learn through relationships with other people. It's about solving problems by talking them through with others, generating new ideas through listening carefully, making suggestions and responding positively to feedback;

hope and optimism: hope is related to initiating and sustaining progress towards a goal and hence it is closely related to optimism and self-efficacy; and

openness to learning: is about being open to multiple ways of approaching learning. This dimension is on a spectrum from 'fragile and dependent' at one end (likely to give up easily and depend on external validation for each step in a problem solution) and 'rigidly persistent' at the other (determined to keep doing things the way they always have and less inclined to listen to others). Either end of the spectrum is sub-optimal for learning.

An online survey tool asks students a series of questions and on completion it provides immediate feedback on an individual's profile against the eight dimensions of the model in the form of a spider diagram which can be used for reflection and a starting point for changing the habits of mind that shape the way an individual responds to a learning opportunity (see Figure 1).

Implementation

After ethics approval, the CLARA survey was administered to first year engineering students during the Autumn 2017 semester at an urban and a regional university in Australia. Both subjects in which the CLARA survey was implemented were engineering design subjects where students were required to work in small groups to create a project plan, in the case of the regional university, and a 3D printed artefact, in the case of the urban university.

Students at both universities were introduced to the elements of the CLARA profile along with related concepts such as self-efficacy, reflection, metacognition, resilience, agency and horizons for action (Hodkinson and Sparkes 1997). The aim of including this content and related activities in their curriculum was to help them develop a language to think about and talk about their learning, to allow them to assess, monitor and evaluate their current strengths and weaknesses and monitor their progress in development of these personal aptitudes needed for learning. The presentation of the CLARA framework during lecture time was supplemented at both universities by tutorial activities. A tutor training session was run at each university so that tutors could experience the activities that students would be engaged in and ask questions and provide feedback on the tutorial design.

The tutorials were run after students had completed their personal CLARA profile and attended the relevant lecture on the framework. During the tutorial tutors summarized the elements of the framework again then divided students into groups of three or four. Each group was allocated one of nine engineering student personas. The group used the description of the persona to draw a CLARA diagram, identify at least one aspect of the framework that could be improved and then generate actions/strategies that could be taken to improve the identified aspect of learning. The tutorials concluded with each group explaining to the whole tutorial why the CLARA diagram they drew represents the engineering persona and presenting what actions could be taken to develop the identified dimension of the framework.

The engineering student personas are compilations of common characteristics of engineering students. Personas have been used in areas such as health technologies (LeRouge et al 2013) and more generally in product design (Miaskiewicz & Kozar 2011). The aim of using these personas was that students would be able to identify with the narratives of different personas and assess the impact of various characteristics on the developmental trajectory of these personas. This would enable students to discuss and reflect on profiles that are similar to their own, and identify strategies for their own development, without needing to reveal their own profile. Although they are fictional characters personas reflect authentic characteristics of real students. Each persona narrative has been validated with a range of engineering academics and students across the country. Feedback from academics and students was also used to ensure that the group of personas represents major cohorts within engineering programs at various universities. For example, the original group of personas was presented at Charles Sturt University and engineering academics there suggested the addition of a persona with a rural/farm background so 'Andrew' was created. Andrew's description is as follows and provides an example of the types of narrative written for each persona:

> *Andrew grew up on a farm in Western NSW and enjoyed tinkering with tractors, farm machinery, and motorbikes so he decided to study engineering. He worked hard during the HSC and particularly focussed on higher level maths and physics and so found those subjects pretty easy when he hit university. He didn't have to study much in first year and so spent a lot of time with his friends in university housing. He is really social and enjoys living with other people after growing up in an isolated community. However, sometimes his socialising gets in the way of uni and although his strong high school results carried him through the start of first year, as the content becomes increasingly complex he is starting to struggle a bit. Through*

his farming experience, he understands the practical parts of design and making sure things are easy to repair, but he isn't doing as well as he'd like in the project based assignments.

One of his favourite parts of UTS is working with the Motorsports Team. He has really enjoyed getting to know other students who love working on cars. His plan is to go into farm machinery design when he graduates, although he's not that optimistic that he'll be able to find work in Australia and hasn't been able to think about where else he could work instead. He is finding it hard seeing how the skills, knowledge and experience from studying engineering might transfer to a different career path, and remains rigidly interested in farm machinery design.

The complete list of personas and their descriptions is available on the aaee-scholar site (http://aaee-scholar.pbworks.com/w/page/1177054/FrontPage) under workshop materials for the OLT Fellowship 'Identity, Agency and helping STEM students understand learning'. These personas are written for a University of Technology Sydney (UTS) context so UTS-specific details were changed and the descriptions fitted into the urban and regional university environments which are reported in this paper.

Observations were carried out at four tutorials at the urban university to determine how well students were able to use the CLARA framework to describe the learning characteristics of the engineering student persona allocated to their group and generate strategies to strengthen the chosen characteristic.

Both universities set low stakes reflective writing tasks for their students related to their use of the CLARA profile. Analysis of the regional university students' comments is based on their response to the prompt:

What study skills and professional attributes do you believe you could develop further as you progress towards your chosen profession? (hint: The CLARA Framework presented in week 2 is a helpful tool to develop this section)

We also analysed text from students at the urban university responding to the question:

How does the learning profile differ from how you have seen yourself?

Samples were drawn from all submitted text to ensure a mix of overall subject grades, gender, and domestic and international students. Twenty-seven reports were drawn for the regional sample and twenty-four for the urban sample. Individual students were coded according to their overall grade, gender and national/international student status (eg. HDa MI – High Distinction student a, male, international).

Reflections were coded in QSR Nvivo 10 using the CLARA framework as a pre-defined node structure. Instances where students directly discussed elements of the framework or recounted experiences and insights attributable to one or more elements of the framework were coded. Surface level statements referring to the framework without detail or insight (e.g. "my sense making improved on the second survey." - with no further commentary) were not coded.

This paper reports on data drawn from student CLARA profiles, tutorial observations and student reflective writing tasks to investigate whether first year engineering students could use the language of the framework to describe aspects of their own learning and which aspects of the framework resonated most strongly with these students.

Findings and Discussion

At the urban university 499 of 520 students undertook the CLARA survey (response rate of 96%) and at the regional university 350 of 446 students completed it (response rate of 78%). This gave us a total of 849 student CLARA profiles.

Figure 1 shows the averaged results for each element of the CLARA framework at the regional university. Figure 2 shows the averaged results for each element of this framework at the urban university.

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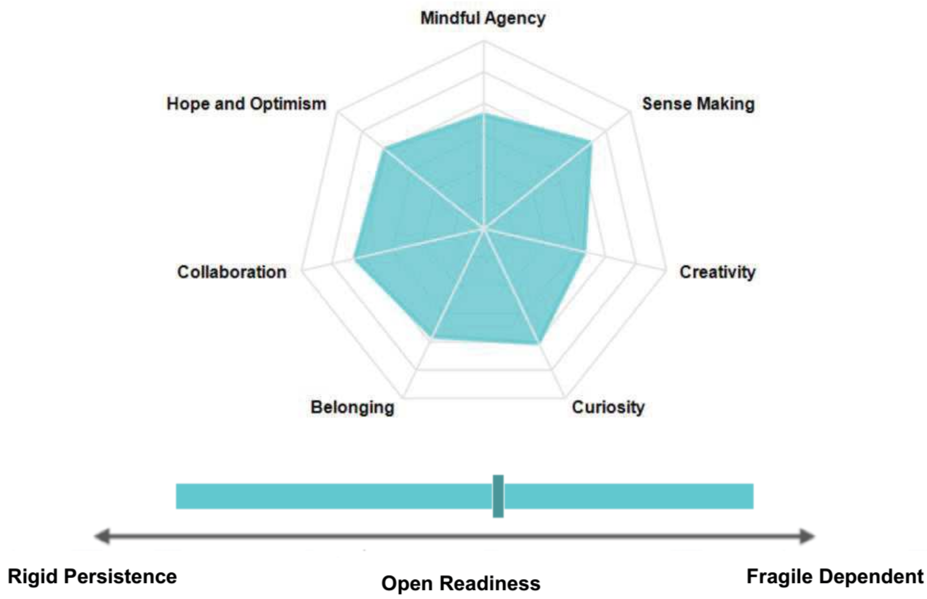

Figure 1: Averaged CLARA profile results from a regional university, n = 350.

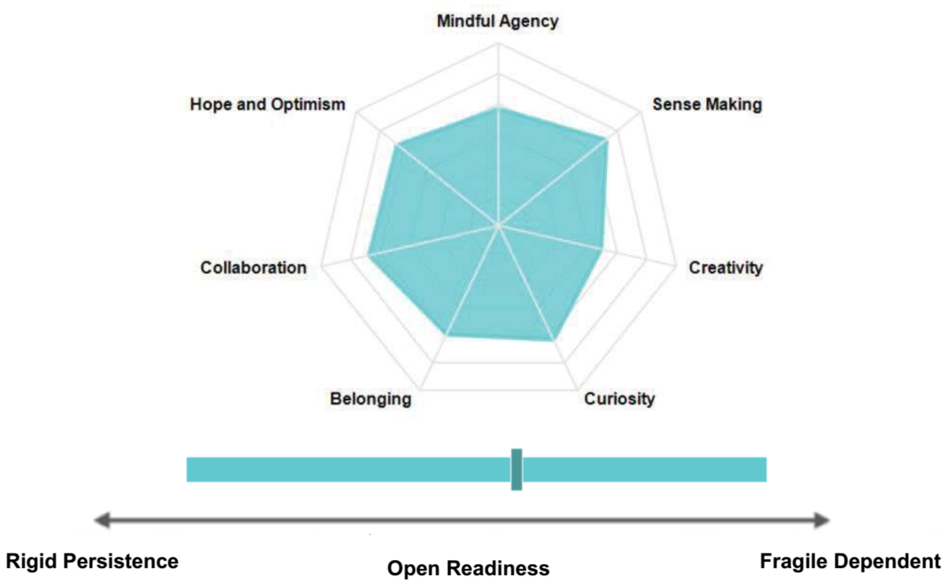

Figure 2: Averaged CLARA profile results from an urban university, n = 499.

The relative shape of the overall profiles for these universities is similar. The early semester results show that these first year engineering students are weakest in creativity and mindful agency, and strongest in sense making and collaboration. Since these profiles were generated from surveys undertaken in week 2 of semester at each university the relative strengths and weaknesses of each cohort is more likely to be a reflection of the NSW secondary school environment than any experience undertaken at their respective universities. These profiles suggest that students in engineering programs would benefit from learning activities designed to encourage creativity. However, to increase retention rates for the first semester of first year we recommend focussing on developing mindful agency and belonging, leveraging of the cohort's relative strength in collaboration to do so with collaborative learning activities

In the observed tutorials student groups generally engaged well although to start with there was some confusion about exactly what the terms in the framework mean e.g. not associating self-efficacy with hope and optimism, not understanding the difference between collaboration and belonging. This was overcome by referring students to the tutorial resource materials which included definitions of each term. They were then able to point to elements of the description of the persona which prompted their rating "We rated her high on belonging because…."; "He shows low creativity here where it says…". Students drew the persona's profiles on the whiteboard so that everyone in the tutorial could see all of them at once and compare profiles.

Student groups typically suggested only one strategy to develop the element of the framework they had identified for development. These strategies were usually not very creative, like 'go to lectures'. This demonstrates the limited horizons of action of many of these first year engineering students and reflects the relatively low creativity result in the aggregated profiles in Figure 1 and 2.

It was interesting that in one tutorial it was suggested that Merindah, Jessika and Regina (all female personas not confident with maths) should think about changing out of the engineering program – this was the only observed tutorial where a group suggested that personas should withdraw from engineering. The option to withdraw from engineering was not suggested for male personas who were similarly not confident with maths, nor for the male persona who was described as having difficulty with writing. The CLARA tutorial exercise prompted this gendered attitude to be articulated and hence potentially interrogated, which may not otherwise occur in typical engineering learning activities.

Reflection Analysis

The distribution of references or comments attributable to each dimension of the CLARA framework are summarised in Figure 3. Most students at both universities mostly commented on mindful agency and collaboration. The regional university students referred to elements of the CLARA framework more frequently than students at the urban university, except for sensemaking (frequency the same at both universities) and creativity (higher frequency at the urban university). The higher frequency of references to the CLARA framework at the regional university may be partially attributed to the fact that the reflective writing task was undertaken at the end of the semester, compared to the urban university where the reflective writing task was undertaken in week 3. The student cohort at the urban university were 44% international students which may also have affected the amount of text they produced. However, analysis of the student texts showed that they were able to use the language of the CLARA framework to describe and reflect on aspects of their own approach to learning, which is what we were investigating. Remaining comments focus on collaboration, mindful agency and belonging.

Collaboration

Comments relating to students' experience of task-focused teamwork and group interaction, and experiences of learning-focused interaction were coded as collaboration. Many comments on collaboration were also related to beliefs, values and intentions for action. These were also coded under other headings such as *Mindful Agency* and *Belonging*.

The regional university subject relied predominantly on team-based learning activities, meaning students' success was highly dependent on the formation of strong working relationships with other students. Unsurprisingly, coding of reflections revealed a strong emphasis on collaboration over other themes. The urban university also incorporated a substantial component of team-based learning, but to a lesser extent than the regional one.

Most comments from regional university students discussed issues of team function in achieving the set assessment task and thoughts on what worked well or what could work well in future. Most reflections included comments attributing learning and academic success to collaborative partnerships and strong teamwork, with a smaller number highlighting team dysfunction as a feature.

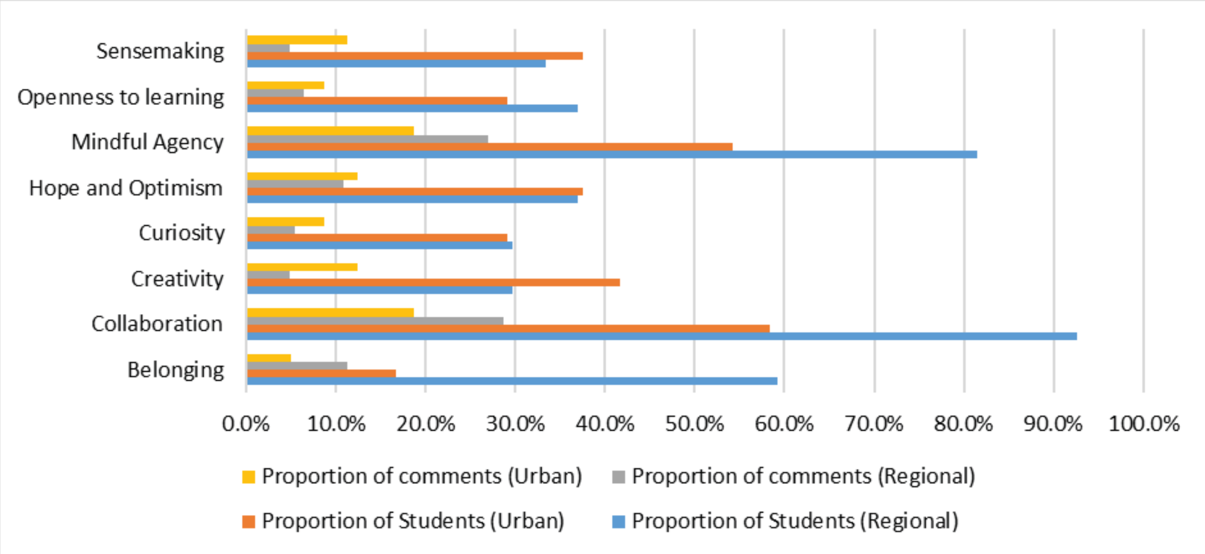

Figure 3: Summary of coding from students' reflective texts

Some students remarked how the team-based approach in the subject had a developmental role, encouraging them to become more collaborative in their approach to learning in contrast to their usual preference for individual study: "As I have always preferred being a solo learner, this improvement is immense, and is one that could still be developed further" (Regional, HDb FD). Of the students who expressed frustration at the poor team function and lack of support from team members, most commented on how their own actions may have contributed to this. Some appeared to see team dysfunction as an outcome of leadership: "What I would do differently is to make sure that each member is adequately doing their work at the start" (Regional, HDd MD). Other students by contrast identified the need to spend more time developing relationships within the team and the benefits of learning to open up to other team members' contributions: "A lot of negatives or areas where I could improve also showed, with time management, organisation, motivation and willingness to listen and adjust to others ideas" (Regional, Cb MD). This contrast highlights different approaches to teamwork – people management vs. collaboration. Suggestions for improvements and personal skill development mostly focused on improving timeliness of individual contributions to team tasks, having more open and honest communication between team members, and addressing problems early.

By contrast, comments on collaboration from urban university students were more focused on learning and approaches to study than any discrete assessment tasks which is in line with the focus presented in their face-to-face sessions. Collaboration was also a less common focus of reflection although still the most common topic overall. Many students valued collaborative approaches to learning. However, comments indicating a preference for individual work or positioning collaboration as a reliance on others were also common:

> *I differ to the results provided as I see myself as one who is able to persist through difficult learning experiences, and although I prefer to work in collaboration with others, I am still able to understand knowledge and concepts on my own (Urban, C6 MD)*

> *I realise I love collaboration and studying with friends, since it can become an encouragement or motivation to me. Studying alone can be boring sometimes, yet for certain studies, I prefer it to be that way because sometimes I rationalise faster and better alone" (Urban, D4 MD)*

This was a feature largely absent from the regional university reflections but may reflect the different nature of the reflection prompts, timing of reflection and design of assessment tasks.

Mindful Agency

Mindful agency also featured strongly. At the regional university this was less often referred to directly, whereas it was usually explicitly mentioned at the urban university. Comments coded as *Mindful Agency* were evidence of students' managing the process of learning – discussing actions taken in response to experiences, discussing feelings associated with learning, taking responsibility for goal-setting, and/or engaging in learning as a process. The prominence of this theme is unsurprising given the nature of the data – a reflective report or ePortfolio entry – but does indicate that students are broadly considering their own responses, feelings, and preferences in learning and the impact of their decisions and actions. Students with Credit, Distinction, and High Distinction grades tended to make numerous and detailed statements with reference to specific events. Students with Pass or Fail grades in the unit overall provided more limited reflections and less evidence of mindful agency.

Reflections coded as *Mindful Agency* were diverse in their focus, but were widely influenced by the language of the CLARA framework:

> *I believe my mindful agency increased due to the amount of planning involved in undertaking such a big project and my need to reflect constantly on previous milestones to improve our marks. (Regional, Cf FD)*
>
> *I'm studying Design in Architecture/ Civil Engineering. These two interlinked fields requires two different learning approaches. For Architecture, I have learnt to value collaboration, sharing of ideas with fellow classmates. The overly competitive classmates often inhibited the studio learning process. Despite the assessments being predominantly individual, we learnt that the fastest way to improve was to learn from each other (in addition to the tutors) (Urban, D5 MD)*
>
> *With the amount of stress, I believe that I was not mindful of most of my actions. Most of the semester, I had to do certain things because I had no other option. I never took time to reflect which is why my mindful agency did not increase. (Regional, Dc FI)*
>
> *However, I didn't realise I lacked in the mindful agency department that much but seeing it in my answers and responses has really opened my mind to what else I could be lacking in... My lack of persistence will probably be my downfall in future and seeing my learning profile has put it in a way so it's clear to me… I knew that I tended to follow a certain way and how I was taught and I knew that I didn't try to create my own methods for solutions because I didn't try to expand on it and think outside the box. (Urban, D6 FD)*

Some students also commented on aspects in their profile which did not change and reflecting on why this may be the case. Other students did not refer to the survey results at all, but still used the language of the CLARA framework. Interestingly, despite direct advice in the assessment criteria, around one third of students in the sample did not refer to the CLARA framework at all. Reflections that did follow the framework tended to address a greater range of learning experience.

Overall, few students' reflections provided evidence of Mindful Agency *during* the semester with the exception of developing collaborative skills and addressing team function. Plans or developmental goals were put forward as future responses to feelings, learning experiences, decisions and choices over the whole semester. To support students in their development of mindfulness and agency, more regular prompts for reflection may be required.

Belonging

Comments coded as *Belonging* referred to individuals' sense of connection to others, to the university, and to the profession. The regional university students' reflections were submitted at the conclusion of a team-based design unit which for most was a first year, first semester unit. The unit itself had been designed in part to help students make connections in their transition to university. This was apparent in students' reflections on their sense of belonging. Students' tended to discuss their interaction with team members and other members of tutorial classes over the course of the semester as either fostering a greater sense of connection, or diminishing it. Of the 16 students in the sample who made reference to their sense of belonging, only four referred to it in a negative sense. All four negative instances were attributed to language issues as a barrier to connecting with others:

> *…because of my poor English skill, I am worry to discuss with group member face to face, that result in I usually distracted due to I cannot understand their meaning sometimes. (Regional, Fc MI)*

> *The group I was in was most unenthusiastic and when [team member] left it was downhill from there. Being grouped with 2 international students was difficult and I found myself explaining many things to them, missing out on important lessons myself. Overall, it was very frustrating to say the least. (Regional, Pd FD)*

While all reported the need to (or for others to) improve language skills, none of these students reported actions taken to overcome this barrier. This suggests that future focus on developing students' agency as a component of learning skill should pay particular attention to strategies for working through language barriers. Belonging was less commonly discussed by the urban university students, only four making reflective commentary on their sense of belonging. All appeared to conflate *Belonging* with *Collaboration* which suggests that understanding of *Belonging* as defined by the framework was less well understood by this cohort. Again, this may be a result of having 44% international students at the urban university.

Conclusions

Findings from this study show that incorporating a learning framework into the curriculum of engineering subjects helped students develop a language to think about and talk about their learning. This allows them to assess, monitor and evaluate their current strengths and weaknesses and monitor their progress in development of the personal aptitudes needed for learning. The aggregated profiles show that these first year engineering students are weakest in creativity and mindful agency, and strongest in sense making and collaboration. These profiles suggest that students in engineering programs would benefit from learning activities designed to encourage creativity. However, to increase retention rates for the first semester of first year we recommend focussing on developing mindful agency and belonging, leveraging of the cohort's relative strength in collaboration to do so with collaborative learning activities. Furthermore, the specific tutorial activities provided an opportunity to identify and discuss otherwise unexamined attitudes to who 'belongs' in engineering.

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Mechanical engineering students' perceptions of workplace mentoring: A case study at a South African University of Technology

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SESSION: C1: Integration of theory and practice in the learning and teaching process

CONTEXT Work placement, a form of work Integrated learning (WIL), is a planned period of learning in industry that is intended to give students practical experience of their field as well as meet specified learning objectives. Researchers claim that effective mentoring is one of the antecedents of successful student learning during placement. In South Africa, the National Diploma in Mechanical Engineering has a prescribed work placement duration of twelve months. From 2019, the work placement duration will be reduced to six months. The reduced duration demands accelerated workplace learning, that can be achieved through adoption of strategies such as effective mentoring, to offset the WIL benefit tempering effect of the shortened duration

PURPOSE The research question for the study as follows: How do various conceptions and elements of workplace mentoring influence mechanical engineering students' perceptions of its effectiveness?

APPROACH This paper reports on a qualitative study that is based on 21 cases of mechanical engineering students from a single university of technology in South Africa. Qualitative data was collected through interviews, and from student work placement logbooks. The data was analysed using the Miles and Huberman's approach to develop patterns, themes, and clusters which were then compared with the core concepts of traditional and cognitive apprenticeship frameworks.

RESULTS It emerged from the study that the efficacy of mentoring during work placement depends on the interaction of pre-placement expectations versus work practicalities, perceived mentor qualities, mentoring functions, mentor-protégé relationship and the learning environment. Pre-placement expectations clouded the students' judgement of the quality of mentoring that they received during their placement. Unrealised expectations affected how they perceived their mentor, how they participated in the mentor-protégé relationship and their response to the industry mentors' mentoring functions. The learning environment during placement provided an opportunity for students to recognise limitations in their own knowledge and afforded them the opportunity to develop learning strategies that they can use to acquire industry specific heuristic tactics that are essential for competent performance.

CONCLUSIONS The study found that pre-placement expectations vs work practicalities-, mentoring functions, mentor-protégé relationship and the learning environment are the key drivers of the mentoring process and the resulting workplace learning. The study also found that most WIL mentoring is ad hoc. Industry mentors adopt mentoring functions that are not aligned with a particular apprenticeship approach. The adopted techniques fit in-between traditional and cognitive apprenticeships.

KEYWORDS workplace mentoring, work placement, students' perceptions

Introduction

Work integrated learning (WIL) in the form of work placement has been part of the diploma offerings of South African Universities of Technology since their inception. Work placement is a planned period of learning in industry that is intended to give students practical experience in their field, as well as meeting specified learning objectives. Helyer and Lee (2014) claim that the work experience provided by WIL is one of the best ways to improve student employability. Tong and Kram (2013) claim that the accelerated learning curves that have been shown amongst mentored workers, highlight mentoring as one of the strategies that can provide faster competency development.

The duration of work placement for the post-1993 mechanical engineering national diploma programme is twelve months. This is about to change as the diploma, in its current format, is going to be phased out in 2019. It will undergo several changes and will henceforth involve a work placement duration of six months. This reduced work placement duration demands accelerated learning to offset the WIL benefit tempering effect of the shortened duration (Coll et al., 2009).

Eby, Brown, and George (2014) define mentoring as a dyadic developmental relationship embedded within the organisational context between a more experienced individual, a mentor, and a less experienced individual, a protégé. They note that mentoring can be formal (initiated by an organisation) or informal, even naturally occurring (initiated without organisational involvement).

Mentors provide both vocational and relational support to their protégés. Lankau and Scandura (2002) indicate that vocational support is geared towards facilitating technical learning within the context of work. The mentors provide their protégés with learning opportunities and guidance that promote development of technical competency. Lankau and Scandura (2002) further indicate that relational support assists the protégé to understand the interconnectedness of workplace roles, functions, and people. They explain that mentors also expose their protégés to their networks, providing them with access to expertise and views that would otherwise not have been available to them.

Vocational mentoring during WIL mostly takes an apprenticeship-like approach. During WIL, mentoring can be ad hoc or take the form of either traditional apprenticeship or cognitive apprenticeship, depending on the nature of the skills that are to be taught and the circumstances of the workplace. Collins and Kapur (2014) state that during traditional apprenticeship, an apprentice works very closely with the expert, referred to as the master, and is supervised in every aspect of the learning experience. Collins, Brown, and Newman (1987) indicate that traditional apprenticeship focuses on teaching skills in the context of their use: within the situated learning environment. They claim that the skills that are to be learned are inherent to the task itself. Collins, Brown, and Holum (1991) explain that traditional apprenticeship is suited to teaching performance of tasks whose required skills are externally visible; that is, readily available to the student for observation. In their view, traditional apprenticeship is amenable to teaching crafts such as welding, boiler making, fitting, and turning and plumbing.

Brown, Collins, and Duguid (1989) explain that cognitive apprenticeship differs from traditional apprenticeship in that it focuses on cognitive aspects of performance, rather than psychomotor skills. Both traditional and cognitive apprenticeship use observation, coaching, and scaffolding as teaching and learning strategies (Collins, 2006). However, cognitive apprenticeship extends teaching to include the mostly cognitive strategies of articulation, reflection, and exploration. Collins and Kapur (2014) claim that cognitive apprenticeship promotes competency development by bringing the master's strategic knowledge into the open, thus allowing the apprentice to engage with it. They state that the acquisition of strategic knowledge allows apprentices to generalise learnt skills; to know when a certain skill is applicable and to be able to transfer their gained skills to novel situations.

Eby et al. (2014) write of the challenges they face in giving practical advice to mentors and protégés on how to develop effective and beneficial mentoring relationships. They attributed these challenges to the gap that exists in literature regarding causal mechanisms of effective mentoring. They propose personal learning as one of the causal mechanisms for effective mentoring.

This paper proposes another causal mechanism, namely the protégé's perception of the effectiveness of mentoring as a teaching and learning strategy. In contextualising this study, the researcher sought to answer the question: How do various conceptions and elements of workplace mentoring influence mechanical engineering students' perceptions of its effectiveness? In-depth understanding of these elements and conceptions would be indispensable to the development of efficacious mentoring strategies that will work in short-duration work placements.

Approach

This paper reports on a qualitative study that is based on 21 cases of mechanical engineering students from a single university of technology in South Africa. The students were selected from a sampling frame of 245 students, using maximum variation purposeful sampling. Maximum variation purposeful sampling is preferred in studies that seek to discover patterns that cut across diversities of experiences. Participants of the study were sampled across nationality, type and location of host company, and prior exposure to work experience. One of the WIL coordinators served as a key informant for the study and assisted in identifying participants who fitted the study criteria.

The study made use of interviews and student logbooks as the primary sources of data. It also used observation to assist the researcher understanding the context of students' experiences. Interviews were transcribed and logbook texts were retyped within Computer Assisted Qualitative Data Analysis Software (CAQDAS). The qualitative data was analysed using Miles and Huberman's approach. Initial codes and categories were developed from the first six cases. These were processed into patterns, themes, and clusters by comparing them with the core concepts of traditional and cognitive apprenticeship frameworks. A further fifteen cases were used for checking the plausibility of the patterns and for verification of the conceptual/theoretical coherence of the clusters and patterns.

Results

Five themes were identified within the mentoring cluster as constituting key aspects of mentoring during work placement: pre-placement expectations versus work practicalities, perceived mentor qualities, mentoring functions, mentor-protégé relationship and the learning environment.

Theme 1: Pre-placement expectations versus work practicalities

Students' evaluation of the effectiveness of workplace mentoring was clouded by their pre-placement expectations. Some of the students' expectations were reinforced by those of the University which were outlined in the learning manual. The University expects mentors to expose and guide students to achieve the University's WIL learning outcomes. Students expected mentors to have a working understanding of the WIL student learning manual. This was not always the case, as highlighted by Student 21:

> *As compared to what I read in my manual, there is a manual that we have for in-service. What I have experienced so far, it's just a complete opposite. When I read the manual, there is expectations from the company and there are expectations from me. There are not into the party, that company.* (Student 21)

It seems, from the students' perspective, that their mentors had to navigate trying to meet the expectations of their employers, the students, and the University while balancing the constraints of daily work. Mentoring is a time-consuming exercise. Consequently, organisations need to free up some mentoring time. This was not possible in cases where senior staff served as mentors and resulted in availability challenges. For example, Student 8, whose mentor was responsible for two branches of the company, reported the following:

> *At the moment, the Quality Manager[mentor] is in PE. He comes maybe once in a week, once a month, to come check this site, how it is, so I tell him, then we write our logbooks, then I ask him to sign for what I have been doing. I interact with him over the phone and all that.* (Student 8)

Theme 2: Perceived mentor qualities

Students' perceptions of workplace mentoring were moderated by their expectations and conceptions of what constitutes good mentoring. Students indicated that they preferred to be mentored by a supervisor who has the following qualities:

1. The mentor should be technically knowledgeable

Students had a low opinion of mentors who were not able to provide solutions to their technical challenges or direct them to where they would get help. If they thought that a mentor was not knowledgeable about something, they tended to avoid the mentor and tried to solicit help from their developmental networks: their co-workers, university peers and family members. For example, Student 1 said the following:

> *I asked my mentor if the thing is going to work, the only thing he said was like, "I have no idea what is going on there"… I speak to the guys, I hear how great their bosses are with them, how much they help the students. Like, most of the feedback I get from other students is how much they enjoy the in-service and how much they get helped.* (Student 1)

2. The mentor should have prior experience of mentoring students

Students preferred mentors who have experience in mentoring students. They believed that such mentors know what is expected of them by the University. Student 4 suggested that one of the reasons for him having a valuable experience was because:

> *There were many students before us. They do run a big in-service programme. I think they're meant to take two every six months.* (Student 4)

3. The mentor should be willing and accessible to mentor students

Students preferred mentors who were accessible and willing to attend to their challenges and concerns. They became frustrated in cases where their mentors had taken a long time to respond to their concerns. Student 5, who indicated that he had a positive WIL experience, reported the following about his interactions with his mentor whom he said assisted him settling in an unfamiliar role of managing mechanical engineering projects:

> *If you have any issues, fabrication, any questions, literally anything you want to know, you go to him. He's more than willing to help. No matter how silly your questions seems.* (Student 5)

4. The mentor should not be too senior within the organisation being unable to spare sufficient time coaching students

Students reported that it was not always a good thing if the mentor was at a senior level in the organisation. They regarded a good mentor to be one who is senior enough to be able to allocate authentic and meaningful tasks to the students, but not too senior so as to be accessible when needed. Students equated seniority with lack of availability. In response to a question on who his mentor was, Student 4 said the following:

> *Yes, it started out as the GM of the company, but the GM was often away and too busy for us, so it ended up being one of the senior project managers that have been there.* (Student 4)

Theme 3: Mentoring functions

Students expected their mentors to coach their integration into the workplace, support them in their learning efforts, and facilitate opportunities for meaningful engagement in work activities. Student 13 aptly described this expectation as follows:

> *The one thing is that a student goes to in-service to be to be mentored, and treated right, and shown how everything is done.* (Student 13)

Students also expected from mentors to ensure that their work activities were properly sequenced, based on their current and expected competence levels. In addition, mentors were also expected to facilitate students' attainment of expected work performance. In most organisations, the students served real organisational functions. Therefore, they were expected to become productive as soon as possible. Sometimes this resulted in students being given complex and demanding tasks too soon. These students felt as if they were thrown into the "deep end and expected to swim".

In other cases, students performed the same functions throughout their placement period. Thus, they continued to perform certain work functions long after their learning potential had been fully exploited. Mentors were expected to ensure that students' work functions served both organisational and competence development goals. Some students were aggrieved that their mentors were more interested in achieving organisational goals, compromising the WIL learning outcomes in the process.

Theme 4: Mentor-protégé relationship

In this study, the mentor was usually a departmental supervisor or manager. Mentorship was assigned based on the person's position within the organisation. It was not uncommon for a mentor to have several protégés. In cases where the supervisor was unavailable, a substitute mentor was assigned. In all the cases, there was minimal choice, particularly from the protégé's side, on who their mentor would be. However, this does not mean that students were passive recipients of mentorship. They exercised personal agency. They actively managed their relationship with their mentor. For example, Student 4 – whose mentor was prone to outbursts of anger – indicated that she maintained a good working relationship with her mentor despite his frequent outbursts by avoiding him when she sensed that he is likely to shout at someone.

> *You become an operator and then you move into the CNC office. Once you're done with that, then you move on to becoming a junior project manager and you manage small projects …. I had a good relationship with my mentor… And he will come back and shout at that person because it took eight hours instead of four. You had to walk circles around him.* (Student 4)

The mentor-protégé relationship was not unidirectional. It was affected by student behaviour, work ethics and proactiveness. Mentors were more likely to allocate meaningful and authentic tasks to students who were proactive. The impact of student personal agency was highlighted by Student 19's experience; she was ignored by her mentor until she proactively asked him to be included in work assignments, which was transformative. Her recollection of the experience also shows that mentors learn from their protégés too:

> *I actually stood up and went to my supervisor and I asked him if I would work outside with the guys. And he didn't mind because to him, it is like I am not even there. Then I went and worked with the guys. After, – it was actually after two weeks – I went to him again and told him that I now want to do maintenance, then he put me with somebody else and then after that week, I went to him again and said that now I want to do pumps. He was actually getting used to the system and that I was there. I started getting invites to the meetings, plant meetings, cost meetings. I started being treated well and all those things. I started travelling to other plants as well.* (Student 19)

Student 19's mentor will likely adopt a different approach should he or she mentor another student in future.

Theme 5: Learning environment

Students expected their mentors to facilitate their exposure to meaningful and authentic work tasks. They also expected their mentors to teach them industry-specific knowledge and heuristic strategies that they would use to tackle work challenges. They recognised that classroom learning does not provide them with opportunities to learn both domain and heuristic knowledge. Student 1 aptly summarised the key limitations of student knowledge before commencing work placement training and how mentors can add to a student's knowledge base:

> *The main thing he helps me on is what we didn't study. We don't know how big a pillow block bearing for this type of problem should be. And where can I get this and where can I get that. But the design is my own. The building and the design is my own but he helps me on where I can get the stuff, will this part fit and the specs and stuff like that but the design work is my own. It's not stuff that one would study from a book.* (Student 1)

Discussion

A key concept that has emerged from the study is that the efficacy of mentoring during work placement depends on the interaction of pre-placement expectations versus work practicalities, perceived mentor qualities, mentoring functions, mentor-protégé relationship and the learning environment. A schematic representation of this interaction is shown in Figure 1.

Pre-placement expectations were the lens through which the students saw mentor qualities. Perceived mentor qualities influenced the way students responded to their mentors. Students developed a negative attitude towards mentors whom they perceived as not technically knowledgeable, unavailable, or unwilling to provide the required guidance. In such circumstances, students turned to their developmental networks for guidance or resorted to soliciting third-party mentoring.

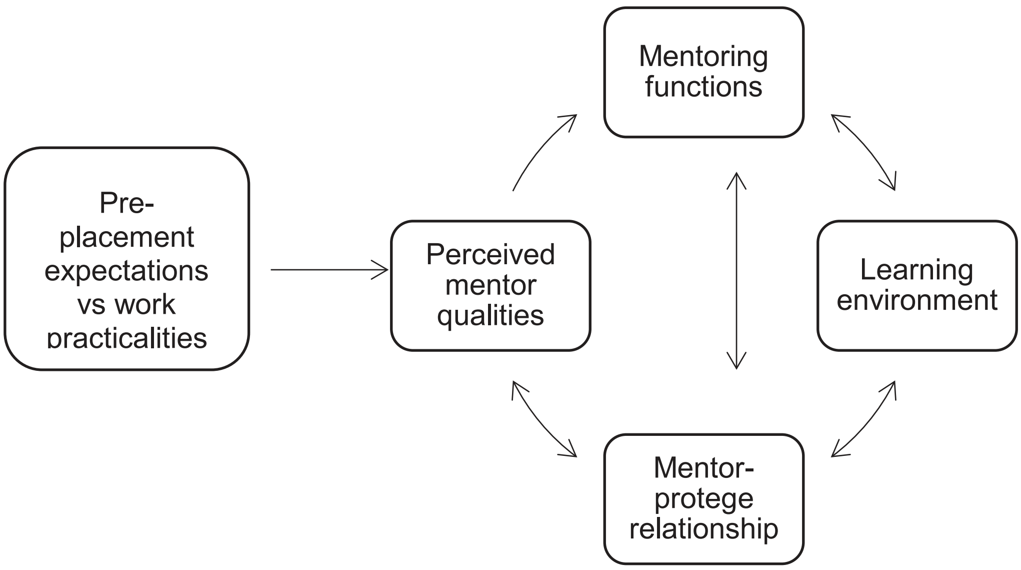

Figure 1: Relationships between mentoring elements during work placement

The mentor-protégé relationship is bi-directional; its development depends on both the student and the mentor. When it thrives, it has a positive effect on perceived mentor quality and the learning environment. On the other hand, poor mentoring and an ineffective learning environment may cause a breakdown in the mentor-protégé relationship, which in turns exacerbate mentoring difficulties. In two cases during this study, such breakdowns in the mentor-protégé relationship had a further reciprocal effect on the mentoring functions and continued to circle out. A fixable challenge, such as mentor availability, produced mentor-protégé conflict that escalated to the point of the protégé leaving the organisation. However, in instances where students felt that they would still benefit from staying on, they found a way of managing the mentor-protégé relationship. As per Bandura's (1997) assertion, students are active participants in their learning. This was demonstrated in this study through student proactivity and its impact on the mentor-protégé relationship.

Mentoring functions also influence the mentor-protégé relationship. Students who were given complex work assignments during the initial period of their placement felt alienated and developed resentment towards their mentors. Students expected their mentors to guide them in their work and to give them time to grow into their roles. One of the students commented that they cannot be expected to master in twelve months the skills that their full-time colleagues took years to perfect. Engineering students in the study by Coll et al. (2009) expressed similar sentiments about the limiting effect of short duration WIL, although the students participating in that study were in work placement only three months. It seems as if the challenge has more to do with the timing of been given complex tasks. Students expected their mentors to protect them from the taxing demands of the workplace. They considered paced learning without the pressure of a full-time job as one of the major benefits of work placement. When that support was not forthcoming, the students developed resentment. It seems as if a mentor-protégé relationship is key to the perceived success of the work placement.

A combination of mentoring functions constitutes a mentoring approach. In this study, mentors mixed and matched functions depending on the circumstances. A mentor would coach and provide scaffolding to his protégé, but would not afford the protégé an opportunity to observe as the mentor performs an activity. In the study, mentors followed an ad hoc approach; choosing what works while considering the time and organisational constraints. The mentoring reported in this study did not follow the sequential phase of cognitive apprenticeship as outlined by Collins and Kapur (2014); it fitted somewhere between traditional and cognitive apprenticeship.

Another key concept that emerged from the study is students' perception of the nature of knowledge that is required for competent performance in the workplace. The students believed that the acquisition of heuristic knowledge and people skills are the major benefits that are gained from work placement. This is similar to the findings reported by Eby et al. (2014) that mentoring aids a protégé's personal learning. The students recognise that the broadness of the mechanical engineering field and the nature of the industry-specific knowledge that is required, make it impossible for universities to address all the knowledge and skills that students require to be work-ready. Work placement programmes provide students with the opportunity to recognise the limitations of their own knowledge and to develop learning strategies that they can use in acquiring the necessary knowledge and skills. They consider the knowledge gained at university as a springboard for obtaining industry-specific and heuristic knowledge that is required for work readiness and employability.

Conclusion

Students' perceptions of the effectiveness of workplace mentoring are clouded by their pre-placement expectations. The study found that pre-placement expectations versus work practicalities, mentoring functions, mentor-protégé relationship and the learning environment are the key drivers of the mentoring process and workplace learning. The study's findings seem to indicate that the mentor-protégé relationship has a pervasive effect on mentoring and learning. Its bi-directional nature is a key influencer of the perceived success of the work placement. The study also found that most WIL mentoring functions are ad hoc. They are not aligned with a particular apprenticeship approach. Lastly, the study found that an effective mentoring process assists students in acquiring industry-specific and heuristic knowledge that is required for competent performance.

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Teaching creativity creatively

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Abstract
The first steps toward innovative technologies in education are often initiated at individual level, especially in small sized universities. Experiencing limitation in resources, teachers hunt for the cost-effective, creative approaches, using open and easy to learn tools, developed and proved models and time-saving methodologies. After implementation of innovative learning designs, they try to justify the benefits for the students. Primarily, learning outcomes and student's satisfaction are evaluated. The paper describes technology-based changes in teaching Theory of Inventive Problem Solving" (TRIZ) course at Lappeenranta University of Technology in a way of roadmap. It aims to reveal changes in learning process, based on student's satisfaction of traditional and flipped courses. The online part of the course is built in a flipped classroom form using open e-learning platform, interactive video hostings and Facebook group for materials delivery. The in-class sessions consists of discussions with originally developed feedback system and problem-solving group works. The data is gathered by the asynchronous surveys provided by the LUT administration and specific surveys, customized by teachers and instructors of the course.
The results in blending of TRIZ course demonstrate how systematic creativity tools assist the inventive course design and address the gaps and drawbacks in teaching. Shared student feedback basically shows positive response to the teachers efforts.

Keywords
Teaching, Flipped classroom, Creativity, TRIZ,

Introduction

Digitalization and total connectivity result in tectonic changes in many businesses. Uber, AliBaba, AirBnB became the biggest taxi, retail or hospitality companies, respectively, having zero tangible assets at the same time. It can be anxiously presumed that global transformation period in education has just began. The main drivers of this transformation are demonopolization, globalization, openness, flexibility and practice orientation. At the same time, the trend of younger generation perception preferences can be added to this: they prefer watching to reading, integration to deduction, multipurpose to concentration. And teaching technologies that enable this transformation are typically named as e-learning or digital education, blended learning, flipped classroom, project based learning and some others.

Having agreed to this, at least partially, “an old school professor” might revise her/his way of teaching and face a number of questions. What should be digitized, flipped, project-based in my course and what should stay as it is? What is the proper share of in-class and “outdoor” (computer-based) activities? How to bridge them? How much time is needed to produce one time unit of teaching video? How to evaluate the efficiency of on-line and in class activities? How technically demanding the digitalization is?

The paper presents rather initial speculation on the subject than solid statistically supported general results. At the same time, a very specific experience of transformation of one of the courses taught at university for a number of years is presented. And this specific teaching experience in rather new and unusual subject, is another focus of the research. The subject is the systematic creativity, grounded mostly in TRIZ, the Theory for inventive problem solving. The approach was introduced in 1956 (Altshuller, Shapiro, 1956) and made it way to the public, industry and science, see recent reviews (Morhle, 2005, Ilevbar, 2014 and Chechurin, 2016). Ironically, the subject should itself be the instrument of inventive changes in the way of teaching. The experience of gradual migration from traditional class to flipped one, the first statistics on results and lessons learnt are supposed to be the main contribution of the report.

Background

Worldwide interest to TRIZ has slightly decreased in the recent years. The amount of scientific papers for the term “TRIZ” in Article title, Abstract, Keywords are currently in the “Fade” stage”. According to Google Trends, the current frequency of search term is low, constituting 30% percent of the maximum in 2004. The interest by region tool shows mainly developing countries in Asia. Worth to mention, that relatively strong surge of interest varies for the regions with the highest proportion of people searching for the term “TRIZ”: Angola (Oct. 2005), Trinidad & Tobago (Feb. 2004), South Korea (Sep.2004), Mozambique (Feb. 2006), Taiwan (Nov. 2006), Brasil (Aug. 2017), Peru (Apr. 2004), Iran (Feb. 2004). The amount of papers in Finland is negligibly small and the overall interest to the term in the country goes down with the highest peak in February 2015.

The inventive design requires special knowledge and innovative solutions. TRIZ is a systematic tool to support idea generation and inventing. Many researchers conclude that companies appreciate introduction of TRIZ approach to business practises (Ilevbare, 2013). Companies are the main consumers of TRIZ education. While service providers are mostly in consulting, the professional TRIZ education, including e-learning tools, remains largely commercial and proprietary. It results in limited information and access to the TRIZ in the open online environment.

TRIZ is taught in a number of universities across Europe, however the hubs remain small. Having been applied to engineering problems, generally it is a part of the programs in Industrial Engineering or Mechanical Engineering departments. Teachers use traditional lecture-based learning design in for TRIZ courses. Scopus database search query TITLE-ABS-KEY (*triz*) AND TITLE-ABS-KEY (*blended* AND *learning*) OR TITLE-ABS-KEY (*moocs*) OR TITLE-ABS-KEY (*e-learning*) OR TITLE-ABS-KEY (*flipped* AND *classroom*) OR TITLE-ABS-KEY (*video*) OR TITLE-ABS-KEY (*online* AND *learning*) yields 18 papers only. 9 papers describe the digitalised ways of teaching TRIZ, two of them describe TRIZ application for classroom digitalisation and others are not relevant. The authors develop the online or blended approaches and environments (Jou, 2010), game based TRIZ learning (Leung, 2007).

TRIZ digital resources for education are limited or old fashioned and do not satisfy the sort of standards of constantly changing user-friendly interfaces. For instance, the acknowledged software packages (Ilevbare, 2013) are either not available *(Innovation WorkBenchs by Ideation International*), or expensive (*Goldfire by Invention Machine, TriSolver*) or seems old-fashioned in terms of design adaptivity (Creax Innovation Suite). First five pages of Google search for term “TRIZ” yield mainly the textual online manuals like “Oxford Creativity”, “The TRIZ Journal”, “Creating minds”. The only one user-friendly tool TRIZ40 that seems to be quite popular, but unfortunately reduces the whole method to contradiction table, a particular and superficial tool. There are some open online courses within the modern e-learning platforms on OpenEDU and 4Brain platforms but they are in Russian language only. TRIZ courses are not found in Linda, EDX, Coursera and other major e-learning platforms. “BioTRIZ” and other personal channels are found in YouTube but not much activity detected. Thus it tells that TRIZ coverage in open online space is small and more powerful learning massive open online resources do not contain any TRIZ courses or even any references to them.

Case

Course redesign (From traditional to flipped classroom)

It was presumed that the creative thinking should be taught creatively, using largely the advances of digital medium changes. 3 year long TRIZ deployment project co-sponsored by Finnish government, LUT and a number of industrial companies (ABB, Konecranes, TuuliSaima and Innotiimi) was used to conduct the training for engineers, analyse the results and redesign the course. Having started with traditional deck of presentation slides the materials were selectively converted into videos and used for regular courses of TRIZ in LUT also.

Pioneered in 2011, the intensive course on Systematic creativity and TRIZ has been taught by the authors at the department of Industrial Engineering and Management of the School of Business and Management of Lappeenranta University of Technology (Finland). Currently, there are two main forms: standard (long) and intensive (short). Long course lasts 1 period (two months) with the total workload of 156 hours (lectures 28 h., exercises 28 h., teamwork 38 h., reading 49 h., exam 13 h.), which is equal to 6 credits. The short-term course within summer and winter school includes two levels of TRIZ “Systematic creativity- TRIZ basics and “Inventive Product Design and Advanced TRIZ course”. The total workload of each course is 78 hours, where lectures and exercises take 24 hours, teamwork and a limited project work are equal to 20 hours, 8 hours of presentations with the results of project work and 26 hours of independent work. The grades are evaluated mainly based on the final project work.

From 2011 to 2015, there were no significant changes in a course design in terms of the structure. The first attempt to re-arrange the course was done within the Summer school intensive in 2016. The target was flipped classroom design, where the in-class time is devoted to activities and pure lecture is substituted with digital preparation materials, mainly videos.

Fig.1 compares the transition from traditional to flipped classroom design. There are three different designs of the same short- term course, which are described in terms of elements and duration of the course. First, the videos were implemented. Following that, the design was extended by quizzes and other materials, which were gathered on the open e-learning platform “Thinkific” as a 6 modules course http://triz.thinkific.com. For the Summer school 2017, the EDpuzzle web-based platform combined videos with instant questions. In addition, the in-class part was activated. The students were randomly grouped in four teams. Each team had its mentor, a PhD student. Class activities consisted of generation of ideas, quizzes, games, role changes, cases, teamwork. Having been implemented, discussion in the beginning of the class connected the online and offline parts. Pure lecturing part was practically eliminated.

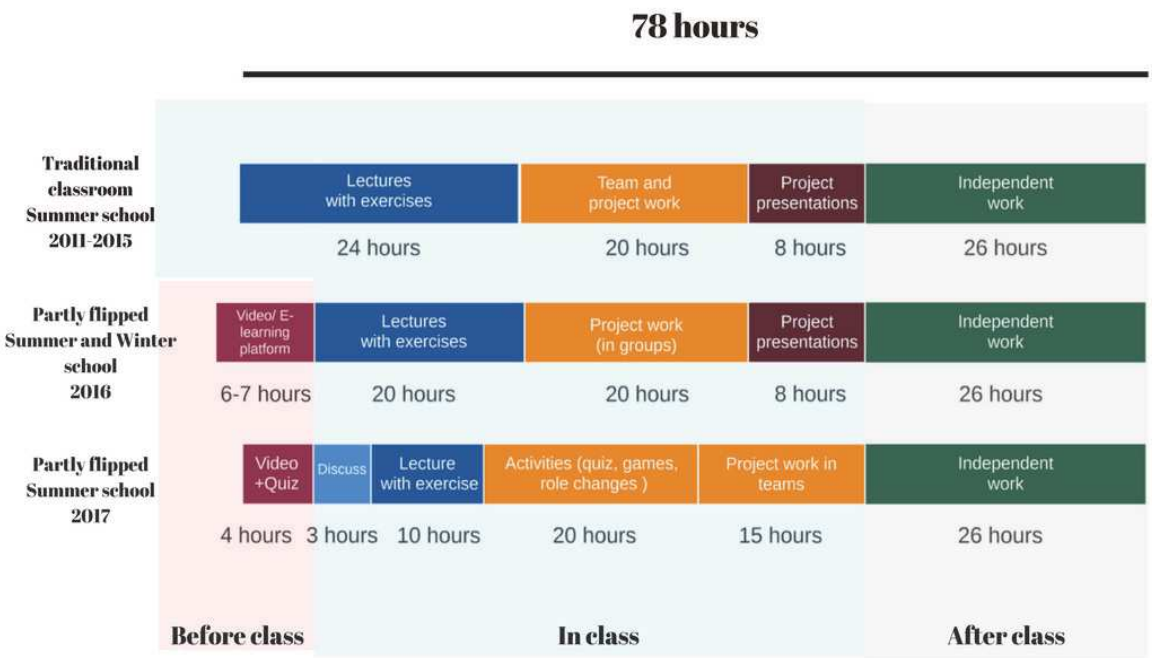


Figure 1: Course redesign from Traditional to Flipped classroom

Instant Feedback system development

The design of the instant feedback system was inspired by the following very generic, even philosophical principles of TRIZ:

- A single useful action should be redesigned periodic, the periodic should become continuous. (“Continuity of useful action” inventive principle)
- A system should be designed dynamic and adaptive. It is to address the challenges and changes from the outside immediately (“Trend of dynamization” of TESE, trends of engineering system evolution)

- Redesign of a system should increase its ideality. Ideal system is the system where even the most aggressive design ambitions, have become true without compromising the cost or any design generated harmful factors (Ideal final result, IFR concept).

These principles were a good departure point (and navigation tool) for the course improvement ideation. They were read as follows:

- Ideally, the teaching session is adaptive, the pace of teaching, the contents, the number of examples, the background of examples and other elements are to be chosen immediately to have its maximum efficiency on the participants.
- The feedback system should enable continuous reading the satisfaction of the audience, especially in the case when the audience is big (visual or verbal personal contacts are limited) or new (requires some time to comfort itself with new teacher/presenter and start reacting more open).
- The system should be light, transparent, easy to use, using the existing resources (no additional devices is needed).

The prototype for the system was found in some advanced universities (like MIT) that practiced an "extra screen" in lecture room. The second screen is used by the audience to tweet immediate feedback, questions or suggestions, openly, visibly but without interruption of the teaching. Being functionally exactly what we wanted to reach, the prototype turned out to be technically demanding. Indeed, it requires one more screen, projector and internet connection (with subscription to either messaging service like Twitter, or web chat room). Instead the authors piloted and experimented the feedback system that delivers the audience's comments to the same screen, over the presented materials. Comparing to Twitter-like solutions, it limits the dialog by one room and gives anonymous access without registration. Unlike voting systems, it does not require special equipment and additional screen like Slido, Tweedback. Communication is initiated by students rather than by professor, whereas generally teachers use feedback systems to get answers on his/her questions. The detailed description and prototype can be found here and tested on Windows PC http://askbox.strikingly.com/. It is planned to improve current solution toward more adaptive and autonomous system which enables not only commenting or questioning but rather to transfer the current class mood to the teacher instantly.

Video recording

To substitute lectures by videos was the most radical, complicated and resource-intensive element in the course transformation. From the beginning, the creative and resource-effective approach for the video design and developments was used. Short (coffee break long) recording meetings and smartphone camera shooting provided the first video samples. They were used as the departure point for more structured and quality recordings later on. 5 core videos (1 hour long in total) covering 5 main topics took 10 hours of professor and 80 hours of assistant devotion. 90% of working time was spent on editing, the rest for the meeting, preparation and recording (Shnai, 2016). The duration of each video was 10-15 minutes with 3-4 inner sections. The video typology was designed based on literature review of flipped classroom experiments and on user-friendly videos in the MOOCs (Massive Open Online Courses). To economize the cost, all videos were recorded using smartphone, tripod with the free access to LUT studio with minimal equipment to control the sound, background and light. Editing and design of videos were done by the assistant using free open software. Subsequently, they were published on the open free YouTube host https://youtu.be/OtHqqQa8Doo. Following that, the videos were embedded in open video or learning management systems like Thinkific or Edpuzzle to integrate them with the full course design.

Data collection and data analysis

To track student's satisfaction two different surveys were conducted. The administration of Lappeenranta University of Technology distributes to students a general questionnaire form on completing the each course. In addition, student's post-course asynchronous semi-structured survey was developed with respect to more specific issues and elements in course design. Questionnaire form was developed based on the rigorous literature review. The data was collected after several days of course completion. Summer school course in 2017 attended 29 participants, mostly of MSc and PhD levels. Course participants' ratio of engineering background students and management was approximately 4:1. There were 3 guest students from China who did not take part in the LUT developed survey. The response rate in general LUT survey was approximately 50% (13 respondents from 26 accounted participants) and in the specific survey, conducted in the class, response rate was 100% (29 respondents from 29 participants). Furthermore, the entire process of flipped classroom implementation was accompanied by observations. The paper presents only partial results about student satisfaction from the latest redesigned course within Summer school 2017. In addition to it, the qualitative guidelines and comments based on our overall experience are given.

Course outcomes

Student satisfaction according to general survey provided by LUT

The student satisfaction for the Systematic Creativity and TRIZ basics was tracked from 2013 to 2017, where the first three years the courses were traditionally designed and last two designed in the flipped form (X-axes). The Y-axes describes the student satisfaction in zero to five scale. Mainly the satisfaction for this course is higher than 4.5. The percentages written on each column show response rates for each course. The number of participants in each year is not vary significantly in a range from 25 to 35. It can be traced that response rate increases and the results of student's satisfaction are more representative (Figure 2).

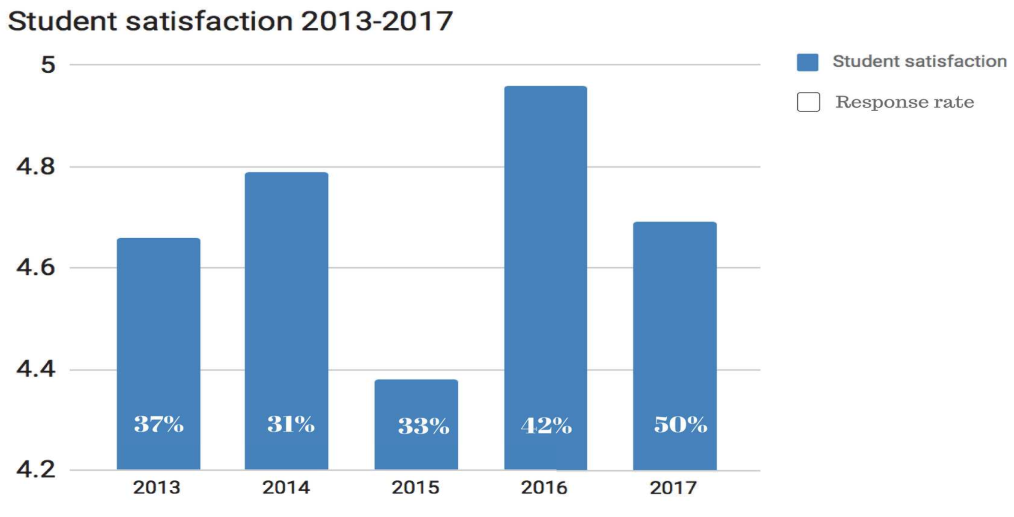


Figure 2: Student satisfaction of Systematic creativity and TRIZ course from 2013-2017

In addition, the student satisfaction by the course "Systematic Creativity and TRIZ basics" was compared to student satisfaction by other courses of Summer school 2017 in LUT. The student satisfaction constitutes average of course satisfaction and lecture satisfaction. Out of 14 summer school courses we analysed the responses on 10 courses, where the more detailed overall satisfaction was given. These courses involve two levels of TRIZ “Systematic Creativity and TRIZ basics” and “Inventive Product Design and Advanced TRIZ “where the first one was designed in flipped form. As on the Figure 2 above, Figure 3 shows the “Overall satisfaction” with response rate.

The courses for 2017 are spread along x-axes. The same as on the graph above, y-axes describes the student satisfaction. And the numbers on each column represent the response rate for the course. The highest response rate is 60 % and the lowest is around 20%. Also the courses with lower response rates have lower satisfaction (Course 3, Course 7, Course 9) and the same in the opposite way (Systematic Creativity and TRIZ, Course 4, Course 6, Course 8). The highest satisfaction rate was for both courses of TRIZ (basic flipped course and advanced traditional course) and Course 8. The response rate for TRIZ courses was counted from 26 participants and for course 8 from 13. It is worth to mention, that the first course of TRIZ (flipped classroom) and course 8 have relatively high response rate in comparison with non-flipped second TRIZ course.

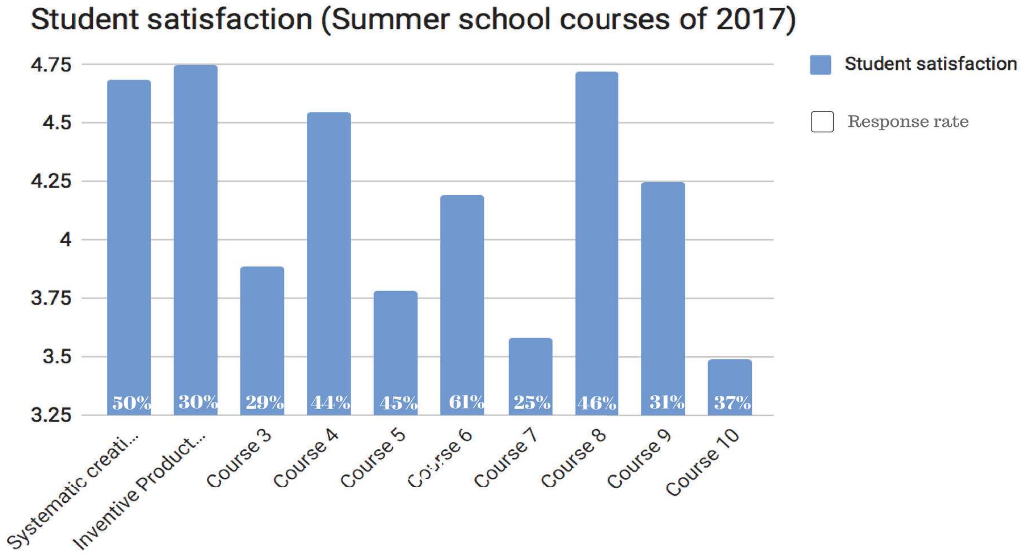
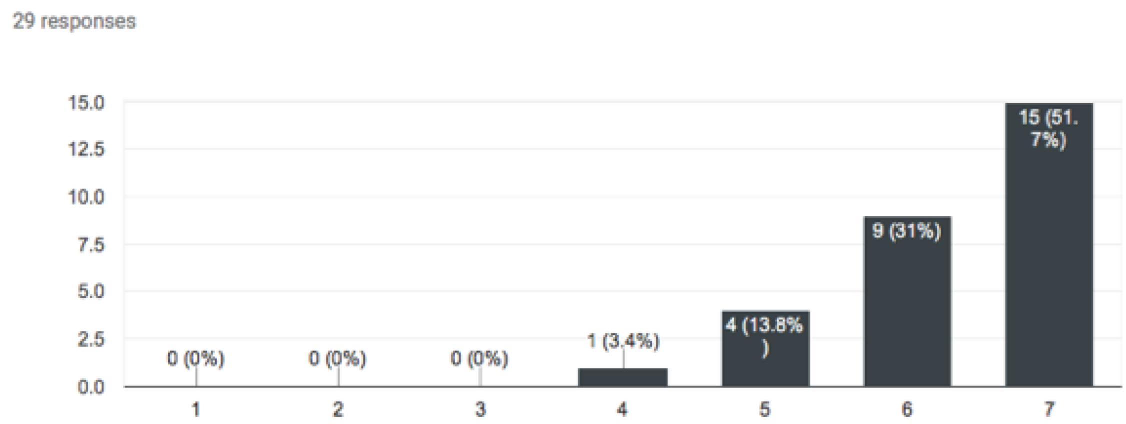


Figure 3: Student satisfaction for Summer school 2017 courses

Student satisfaction (specifically developed survey)

The amount of involved respondents was 29 (26 LUT accounted participants and 3 guests from China) and Response rate was 100%. The main results reveal positive feedback from most of the students. General perception about course design is given on the Figure 4 below. The 7 point Likert-type scale was used to reveal student agreement. Y-axes describe the amount of respondents. The first graph shows the student’s estimation of the usefulness of the course design for their study and the second graph the satisfaction with flipped videos and activities.



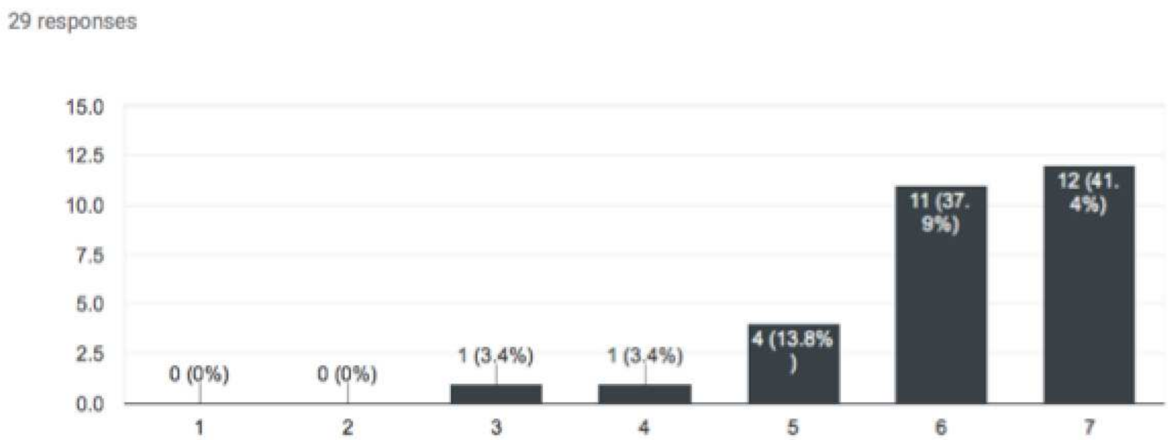


Figure 4. Overall perception of the course

> *"The course has been most interesting and enhanced my capabilities in problem solving. Leonid has truly thrown himself into the fire and is a very inspiring lecturer. Early morning classes are often tiresome and uninviting, but not this one!"*

> *"It has been an incredible course, because I think we have learned many methods without realizing it. I really enjoyed and recommended"*

The student's perception about the videos implemented before the class was also positive. Most of them strongly agree that videos help them to understand the materials better, increase involvement and interest. However, they were not so sure that videos are helpful for preparing questions and comments in advance.

> *"Videos could be more precise, with more details and examples. Though, all these is given in the classroom."*

> *"Well I believe the idea of the video is especially nice because you can go through them even after the course. I would like to questions to be framed better and I think with continuous feedback and improvement, they can be even better"*

> *"Videos were mostly good and informative. The following questions were mostly unusable and annoying in their inaccuracy"*

"It would be better to have longer videos, not so concentrated. When every word is important it is hard to keep concentration on every second during all 12 minutes. May be it is better to add more examples in the video and repeat main points from different angles."

In addition, students support the idea that in class activities increase communication, involvement, motivation to learn, understanding of TRIZ tools, having fun.

"It was nice to have several lecturers in this course, to see and take part in discussions they make. Also I liked the idea of changing activities at certain time (from group work to independent work"

Design guidelines

Some design guidelines and comments can be proposed based on the sequence of experiments with respect to students and professor opinions and learning analytics from the used tools. It seems that most of them can be generalised and probably be helpful not only for TRIZ course re-design.

- Build the bridge between online and offline materials

The connection of online and offline parts is relatively important. By adding the discussion in the beginning of the class the initial level of student's understanding was revealed.

- Course time increase by the preparation materials can lead to student's overload, especially within the intensive course.

It is beneficial if students are familiarised in advance with the flipped classroom structure of the course. And if the in-class time is decreased, motivating students and making them more open to innovative learning approach.

- Share the preparation course materials in advance. Make the preparation materials «not possible» but required
- Give special attention to video typology, design and place in the course

Based on the detailed surveys, the 30 % (from 29) of students believe that "Videos didn't give enough information" and 20% that "Videos are too fast". Therefore, the videos can be improved in these directions. In addition students mentioned that 45% percent of people believe that videos are useful "before the class" and 38% after class.

- Add motivation (like quizzes) to increase the video views
- Involve differently designed activities

Increased time for activities and 4 mentors lengthen the personal communication, avoiding free riders in the class. Teamwork was also beneficial for in-active students in order to open their potential and strengthen their social status in the university environment.

- Begin with the small video fragments development

Learning outcomes

Measurement of the grades is not as simple in the described course, as possible in more fundamental subjects. Whereas, the grade system for math or physics can be standardised, creativity assessment is not subjective and can be interpreted differently.

The grades for this course are commonly constituted based on the final projects reports.The flipped classroom design of 2017 was estimated based on the overall in class work and learning analytics from video views was taken into account in questionable situations. Increased time for variety of different activities, involvement of 4 mentors and relatively small amount of participants for each class team gave the detailed perception about each student in personal.

Conclusion

The study presents the experience and results of digitalization of university course on TRIZ, the theory for inventive problem solving. It demonstrates how principles of systematic creativity assist the inventive course redesign. We feature instant feedback system prototype, original blended course design, dynamic bridging of in-class and off-class activities, focus on project/team work in application to the specific course. Experience based speculations on how to start blending of teaching, what difficulties should be expected and how they are circumvented can hopefully save some efforts of readers, interested in the same activities. Course redesigning is used to support the main outcomes as well as general success of the journey.

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Integrating Professional Practice in the Engineering Curriculum: BE/ME Chemical Engineering Students' Experiences in Industry Placements

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CONTEXT Engineering schools are tasked with the challenge of preparing engineering graduates who are equipped with competencies that satisfy industry expectations and Engineers Australia requirements. This task is particularly challenging because it is difficult to replicate industry-like situations in engineering classrooms. To address this challenge, the Bachelor of Engineering (Honours)/ Master of Engineering (BE/ME) at the University of Queensland (UQ) offers a six-months placement experience which provides the students with an opportunity to engage in industry or research before they graduate, and to apply the knowledge acquired on placement in their last year as UQ engineering students. Although the program seems to be successful, there is no research done or data collected on the program that can provide feedback to the School about the program strengths, improvement areas, and the learning gains the students have by participating in the experience.

PURPOSE The purpose of this research is to investigate the daily work experiences of chemical engineering students in BE/ME placements and the learning gains resulting from participating in it.

APPROACH We used a qualitative study design. For this pilot study, we conducted interviews with two BE/ME Chemical students after participating in the placement program. We developed the interview protocol based on three theoretical frameworks: (i) the PPIR framework by the Warren Centre that explains what professional engineers should be able to do; (ii) the boundary spanning framework that fully unpacks aspects of working with people within an engineering organization; and (iii) the Engineers Australia Stage 1 and 2 Competencies that provide competencies that align with and expand many aspects of the aforementioned frameworks. Interview transcripts were analysed using qualitative data processing software.

RESULTS Analysis of the data identified three main emergent themes. First, students recognised that working and collaborating with other people - rather than siting in isolation doing calculations- is a major part of the engineering practice. Second, students realized the importance of understanding troubleshooting processes and all the other implications of design. Finally, students understood the importance of communication as a key component of engineering, especially in relation to the emotional aspects of working in industry.

CONCLUSIONS This study provides evidence on the students' experience in the placement program. Students recognised that the University has not been able to provide them with learning experiences that were comparable to their placement. Engineering programs need to invest more resources in the development of professional skills like communication, teamwork, and the management of human resources since the preliminary evidence from this study suggests such professional skills are not yet a main focus of engineering education.

KEYWORDS

Work-Integrated Learning, Placement, Communication, Collaboration, Professional Skills, Boundaries.

Introduction

Engineering schools are tasked with the challenge of preparing engineering graduates who are equipped with competencies that satisfy industry expectations and Engineers Australia requirements. This task is particularly challenging because it is difficult to replicate industry-like situations in engineering classrooms. Yet experiences in the workplace, provide one of the most significant learning sources (Lucas, Cooper, Ward, & Cave, 2009). Hence, Universities around the world have been incorporating placement programs in their engineering curriculums to make students more competitive and ready for the workforce. However, Universities need more information on the performance of the placement programs to maximize the success of these types of educational interventions (Hackett, Martin, & Rosselli, 1998).

To address this challenge, the Bachelor of Engineering (Honours)/ Master of Engineering at the University of Queensland offers a six-months placement experience which provides the students with an opportunity to engage in industry or research before they graduate and to apply the knowledge acquired on placement in their last year as UQ engineering students. Although the program seems to be successful, there is no research done or data collected on the program that provide feedback to the Engineering Faculty about the program strengths, areas of improvement, and the learning gains the students have by participating in the experience.

In order to understand the placement experience and learning gains of students in the BE/ME program, we developed a mixed-method sequential study design to collect several sources of data on UQ chemical engineering students that participated and will participate in the program. Specifically, we want to answer the following two research questions:

1. What was the nature of the students' daily work?
2. How has the placement experience impacted their professional development?

Answering these research questions will enable us to paint a very rich and thorough picture of students' experiences during their mandatory industry/research placement, which in turn will allow us to further enhance the experience of future students and provide evidence of the usefulness and value of such types of activities for students, academics, and employers.

In this paper, we report preliminary results from our initial qualitative pilot study. We interviewed two students a few months after the placement and present emerging insights from two of the richest interviews.

Theoretical framework

In this study, we integrated multiple existing frameworks that characterize multiple facets of the professional engineering practice. First we used the Warren Centre's Professional Performance, Innovation and Risk framework (PPIR) (The Warren Centre, 2009). PPIR defines how professional engineers interact with, and respond to, their clients, their professional peers and the community. The framework proposes that professional engineers should be able to 1) be aware of multiple stakeholders, 2) define, scope, and execute engineering tasks in accordance with stakeholders needs, 3) leverage proper resources and knowledge to perform engineering tasks, 4) respond to statutory requirements and public interest, 5) apply risk management approaches, 6) use engineering innovation to enhance an engineering task, 7) apply appropriate management protocols and standards, and 8) follow contractual agreements (The Warren Centre, 2009).

Second, we used the Boundary Spanning framework (Jesiek, Trellinger, & Mazzurco, 2016) that provides a unique lens to understand the realities of engineering work as experienced by practising engineers. The framework fully unpacks aspects of working with people within an engineering organization: including classification of types of boundaries (cultural, educational, demographics, job role, organizational) and boundary spanning activities (managing information, coordinating, networking, representing and influencing). This framework cuts across and expands many of the dimensions of the PPIR framework.

Finally, we used the Engineers Australia Stage 1 Competencies. Engineers Australia developed competencies that represent the knowledge and skill base, engineering application abilities, professional skills, values and attitudes that must be demonstrated by engineers at the point of entry to the engineering practice.

The integration of the dimensions of the three aforementioned frameworks provided a solid underpinning for the study.

Methods

Although our overall project is a mixed-method sequential study, this paper focuses on the pilot of the first stage of the project (i.e. qualitative interviews). In this section, we describe the qualitative methods used to better understand students' experiences in the placement program. The purpose of this study is to understand what the nature of students' daily work is during the placement experience, and how the placement program impacted their professional development. Since our primary objective is to understand students' experience with the program, qualitative methods that provide rich descriptions are appropriate (Creswell, 2013; Leedy & Ormrod, 2005).

Context

The BE/ME placement course is a key feature of the 5-year, integrated BE/ME program that UQ launched in 2012. BE/ME students undertake a 6-month placement in industry or research in their 4th year of study and then return to university with a wider engineering perspective to complete 5th year masters courses. The BE/ME placement program was first trialled in the School of Chemical Engineering in 2013 when 6 students were placed in industry and research. Today in 2017, there are 27 chemical engineering students enrolled in the placement course and another 36 students enrolled in other engineering disciplines. To date, the experience of students on placement has been monitored via a series of course assessment items including monthly reflective journals and project progress reports. This study allows us to explore the experiences of students in more detail and in a forum outside the formal course assessment schedule.

Participants

The participants of this study were chemical engineering undergraduate students that participated in the BE/ME placement program during the semester 2 2016. For the pilot of this study, we selected two participants from the program and conducted a semi-structured interview. Interviews were conducted with participating students the semester after they participated in the placement program. Participants were invited over email to participate voluntarily in the interview, and there was no compensation for participation. The study secured ethical clearance.

The first participant is Carlos, a male engineering student. He worked for a sugar mills company. His job was to document standard operating procedures for the gas boilers. Maria, the second participant, a female engineering student was placed in a water treatment plant. Maria's job was with the process control and efficiency team working on energy optimisation and chemical optimisation.

Data collection

Data were collected using semi-structured interviews. The interview protocol was informed by the three theoretical frameworks used for this study. In the protocol, students were asked questions about their experience in the placement, their typical duties and responsibilities, and their interactions with others. Students were also provided with an example from the Boundaries Spanning theory and they were asked to reflect on the example according to their placement experience. The interview protocol was tested with other researchers. Those interviews were not included in this study since the main purpose was to improve the questions and procedures of the final interview protocol. After being selected, students were contacted by email to set a time and place of their preference. The interviews were conducted in a private location. A consent form was developed and read to the students before the interview started. After discussing the consent form the students signed it and the interviewer started audio recording the interview. Interviews lasted no more than 50 minutes.

Data analysis

Thematic analysis methods (Clarke & Braun, 2014; Robson & McCartan, 2016) were used to analyse the data. Thematic analysis is defined by Braun and Clarke (2006) as a method of identifying, analysing, and reporting patterns within qualitative data. According to Robson and McCartan (2016) thematic analysis is a generic qualitative method that allows data to emerge from patterns after doing open coding of the transcripts. Since our interest was to identify, analyse, and report the patterns of the interview data, the use of thematic analysis is appropriate to guide this study. Robson and McCartan (2016) suggest that thematic analysis can be used to better understand “experiences, meanings and the reality of participants” (p. 474).

Following thematic analysis procedures (Braun & Clarke, 2006; Robson & McCartan, 2016), recordings of the interview were transcribed by the researchers to increase familiarization with the data. Pseudonyms were used to ensure anonymity of the participants, and some information like name of courses, professors, and projects were changed. Notes taken during the interview were included when analysing the data to facilitate the development of memos. Codes were developed and two different researchers compared initial codes and agreed on the coding system. Once all parts of the data were coded, codes were grouped based on their similarities into themes. To ensure trustworthiness of the process, two researchers coded independently all the interviews and grouped the codes into the themes developed to establish inter-rater reliability. In instances when codes did not match, researchers discuss the codes until agreement was reached. The MaxQDA software was used to code the interview line by line.

Findings

Investigating students’ experiences in the placement program helped identify the way students understood their daily work, as well as, the impact of the program in their professional development. Analysis of the data identified three main emergent themes. First, students recognized that working and collaborating with other people - rather than siting in isolation doing calculations- is a major part of engineering practice. Second, students when solving real problems realized the importance of understanding troubleshooting processes and all the other implications of design. Finally, students understood the importance of communication as a key component of engineering, especially in relation to the emotional aspects of working in industry. In the following section, we elaborate on each theme and provide some examples of students’ responses that informed the development of the themes.

Collaboration

Both students recognized the importance of understanding how to work with others during their time in the placement. For the participants, collaboration was something they not only valued but something they needed to learn. They realized the importance of collaboration beyond technical contributions to projects, but on developing long lasting relationships not only with peers at their same levels, but also with operators and people at every level of the company or institution. They recognized the importance of the experience of people in the company even when they didn’t have engineering degrees. Carlos commented:

> Learning how to deal and interact with operators is really important and is not related to how good you are regarding technical skills, but rather to how good you are being able to “win” them over.

Maria also commented on how important the operators were for her job:

> The operators actually were almost like family because they really showed me the ropes. They would show me around, give me tours, tell me how to sample, and everything….I actually learnt a lot from operators: they know the practical side so well, and we might have all the head knowledge but our head knowledge might not always match what's really going on in reality, and they do know that.

Furthermore, students saw the importance of social interactions as a bridge to develop specific knowledge about the job. Carlos explained how they created a work group in order to learn more about boilers: “so no one was overly experienced with boilers, so we formed an internal boiler work group and it was the best experience.”

However, students needed to learn the best ways to interact with other people, since they felt that was something they didn’t learn at University. Initially they thought interactions were based on knowledge or practice, however, they realized that interactions were about the social aspects and developing relationships of trust. Maria affirmed:

> So obviously interacting with them is interesting in that when you’re a university student coming into their workplace and asking them a lot of questions, sometimes you can get some heated responses, or some interesting interactions. So you’ve really kind of got to play into that and have a bit of fun with them really, it’s a good way to get them on side.

In sum, it was apparent from the interviews that the placement helped them appreciate the importance of building trust with many different stakeholders in order to being effective in completing their assigned tasks.

Solving real problems

Students also emphasized how different it was to solve problems during the placement as compared to solving problems in the classroom. Participants were not prepared to find high levels of uncertainty in the job, nor to find gaps of knowledge between the theoretical information they had and the on-site application of knowledge they required. As Maria said: “there was a huge difference between learning the theory in the classroom to actually apply knowledge and learn how testing works in reality.” Likewise, Carlos also mentioned:

> It’s not all straightforward, plug and play calculations - so when you actually get a massive data set, and half the data is not right, or it’s not a good period to take data and stuff like that. That’s more real life, and draw conclusions…. but the importance is in just learning how to behave in a professional environment and learning how to react in certain situations when things don't go as planned.

Students also recognised the importance of experience over memorisation of technical knowledge. In Carlos’ words:

> So it took me a while to memorise and to learn and read the procedures and know how to do it accurately. And I could not always get the first time, so I had to always repeat a few times which was very interesting as well, because the way these guys learned how to fix a situation - say the pH is moving out of thing, and they go to the pump that controls the pH regulation, they’ll just tweak it by knowledge of what they’ve done in the past.

To solve problems students realized that the balance between experience and theoretical knowledge is very important. It also made the students very aware of an important aspect of the engineering profession, and that is to be critical when understanding what the best practices are in the discipline. Carlos elaborated:

> …the biggest challenge was probably figuring out what is best practice, that's probably one of the bigger ones, which is why we formed that internal work group. But even still, deciding what's best practice is always a tough thing.

Maria included the importance of effective collaboration with operators as a way to finding the best practices to solve problems:

> I would come to them with a list of things. I said, well, is this the best way to do it? Then we would have conversations about let's do it this way - yeah, no that way's fine. So that's how we decided what best practice was.

Furthermore, for the students, the placement experience was something very valuable that they said they couldn't obtain in a classroom setting. They understood that solving problems had to do also with troubleshooting, uncertainty, and finding alternative ways to apply knowledge. For instance, Carlos realized that problem solving is not only about designing something new, but it also comprises troubleshooting and optimizing existing systems:

> I guess I wasn't really sure what exactly on-site process engineers do, because all the stuff we really deal with in chemical engineering as a degree I would say is mainly design. We deal with this is what this unit is, and how it works, and how you build it. We probably don't deal that much with this unit exists, and it's doing this, it's misbehaving, or, how do we go about increasing the throughput through it?

Overall, this experience changed the way they understood the profession:

> …and I felt like that was really helpful, rather than just sitting on a desk and just having a desk job. I found that skill - I don't know what skill you would call that - but just like the real practical application- to be one of the best I can have as a future engineer (Carlos)

Communication

Another aspect of the placement program that both students talked about was the importance of communication. Students considered that the success of their placement was highly related to how well they could communicate with others; they saw communication as one of the main aspects of the job. Maria commented:

> I'd say a lot of my job was communication, trying to figure out I want this bit of information, how do I get it? So trying to find out where all the things that I needed were. Yeah, talking to the operators, so that's communication.

Also, Carlos commented on communication:

> Yeah I was talking to a lot of people all the time, and because every time you changed site all the people change as well, you've got to do the whole thing all over and get to know who's who and figure it all out again.

Participants expressed that the most important and difficult part was to understand how to communicate with operators. Being able to communicate in their same language led to productive collaboration and working relationships. Carlos explained his process:

> I would go on site, talk to the operators, figure out the draft of the SOP, figure out the best way to do it. Once we decided what the best way to do it was I'd put pictures in of every step, so I had to go around on site, take photographs of everything - which was interesting, trying to find things. Then I'd take it back to the operators, and I'd say 'hey - is this good? Do you understand this? Does this all make sense?'

Carlos also explained how learning to communicate with operators represented a challenge that he could overcome with patience and good communication skills, but was not expecting to spend so much time dealing with these type of situations:

> So one shift will just not even talk to me. I'd come into the operating room, or try and talk to them, just nothing. At that site, I wasn't really getting anywhere, even with the operators that did want to talk to me, we weren't really making any progress, so I went to the plant supervisor there, and I said 'hey, look I'm not making any progress here'. By the time I finished, he was inviting me over to his house for dinner and stuff like that. So it was really a case of I think going to a site like that you definitely have to have thick skin, which I already had. I refereed soccer for five years or so.

Conclusions and Future Research

This paper presented information from a pilot study to better understand the experiences of chemical engineering students in their placement program. After analysing data from two interviews, three main themes emerged across both interviews: (i) the importance of collaboration in the placement experience, (ii) the contingency of solving and troubleshooting problems in the real world, and (iii) the importance of communication in the engineering profession. Although students felt they were prepared technically for the placement experience, they realised that they were missing some training on the importance of these three themes. Students recognised the placement program to be transformative in their professional development, and explained how the placement experience is positively impacting the courses they are taking in their last year.

For the next step in our research we plan to continue the qualitative data collection by interviewing all the students in the placement program cohort in 2016 and 2017. In addition, data collected in this study is helping us develop a survey that will allow us to collect data quantitatively (i.e. pre-and-post test) to determine the specific impact the placement program is having on the student learning and development.

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Engineering Student Use of Facebook as a Social Media 'Third Space'

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CONTEXT In the context of engineering education, the potential of social media to open new modes of communication, interaction and experimentation between students and teachers has been identified. Facebook (facebook.com) is a popular social network system, with hundreds of millions of users, and examples of its use in engineering education can be found documented in the literature. A systems view of engineering education would typically position social media as a communication space that is either: i) controlled by the university for academic purposes; or, ii) controlled by students for social purposes. An emerging area of social media research is the investigation of student-created Facebook groups as a 'third space', between the institutional space of teacher-managed Facebook groups and the non-institutional, student personal space of the Facebook network.

PURPOSE This paper investigates and characterises public Facebook pages and groups relating to engineering at Deakin University to determine if they exhibit the distinctive characteristics proposed in the literature for student-created 'third space' Facebook groups.

APPROACH A search was undertaken to locate public Facebook pages and groups relating to engineering at Deakin University, and the posts and comments from those pages were captured. The Facebook data were graphed to visualise the frequency of posts and comments over time. The text content from the posts and comments was analysed using text analytics and the results visualised to show major themes present.

RESULTS Five Facebook pages and six Facebook groups where identified, containing 1484 posts and comments, and more than 51,400 words. Visualising the frequency of posts and comments showed highly variable levels of online activity between the different pages and groups. Text analytics visualisations of the post and comment content showed the distinctive characteristics proposed in the literature for student-created 'third space' Facebook groups.

CONCLUSIONS The public Facebook pages and groups relating to engineering at Deakin University were largely student-created, and exhibited the distinctive characteristics proposed in the literature for student-created 'third space' Facebook groups. For engineering educators, the pilot investigation documented in this paper offers another method for analysing and understanding the content of online discussion spaces, including student-created Facebook groups relating to their studies, and discusses implications for engineering educators of the emergence of student-created social media third spaces for learning.

KEYWORDS Social media. Facebook. Text analytics. Third space.

Introduction

Social networking systems (SNSs) are one of many communications technologies that have been widely adopted by students of all ages, and hence have the potential to be a valuable contributor to education (Roblyer, McDaniel, Webb, Herman, & Witty, 2010). Online learning management systems (LMSs) are now ubiquitous in higher education, and while typically providing useful features for education administration, they often lack effective tools for the support of online social communication (Al-Atabi & Younis, 2010; Irwin, Ball, Desbrow, & Leveritt, 2012). It is suggested that social interaction is an important indicator of education quality, so it is natural that, as SNSs have developed alongside the adoption of LMSs, many educators have looked to SNSs as an additional online communications channel that could be used productively in education (Roblyer et al., 2010). Facebook (facebook.com) is a popular SNS, with hundreds of millions of users (Aharony, 2012; Irwin et al., 2012). There has been a long-standing natural affinity between Facebook and higher education, as the platform was originally designed for US students to use on-campus (Gafni & Deri, 2012), and initially requiring a '.edu' domain email account to register (Mathews, 2006). Now open to, and used widely by, the general population outside of universities (Roblyer et al., 2010), self-reported use of Facebook by students is very high, and, not surprisingly, universities have investigated the educational uses of Facebook (Gafni & Deri, 2012). Students generally come to university well-versed in the use of technology and social media, so even though Facebook was not specifically designed with education applications in mind, it has transitioned from being purely a SNS to being used in many areas of student life, including education, with many students mentioning education and specific items of school work in descriptions of their use of Facebook (Roblyer et al., 2010).

In the context of engineering education, the potential of social media to open new modes of communication, interaction and experimentation between students and teachers has been identified (Kamthan, 2010). Documented applications of the popular microblogging service Twitter (twitter.com) include: the use of Twitter to engage a large group of engineering students during an information literacy class (Morrow, 2010); the use of Twitter by engineering students on work integrated learning placements (Paku & Lay, 2011); and, the use of Twitter by students to send commands to a hosted installation of the numerical computing environment Matlab (Judd & Graves, 2012). The examples in the literature of the use of Facebook in engineering education are no less diverse. Including: social media tools (including Facebook) being used to link software engineering students with practicing industry professionals (Morgado et al., 2012); a liaison librarian using Facebook to interact with engineering students (Mathews, 2006); the use of a Facebook group to support students in a unit on thermodynamics and heat transfer (Al-Atabi & Younis, 2010); Taiwanese engineering students learning English and using Facebook to practise making English sentences (Wang, Sheu, & Masatake, 2011); and, software engineering students collaborating at two universities autonomously adopting Facebook for group communications when the provided communication system proved unwieldy (Charlton, Devlin, Marshall, & Drummond, 2010). It is this latter, student-created use of Facebook for educational purposes that we are interested in here, using the framing concept of a social media 'third space'.

The idea of the 'third space' is attributed to Bhabha (2004), arising from postcolonial critique of political hegemony, and the desirability of creating a dialogic third space where neither the speaker's nor the listener's meaning is presumed to be 'correct'. It is in the intersections and overlaps between spheres that discourses not possible in existing settings can occur (Aaen & Dalsgaard, 2016). In education, the concept of dialogic third space can incorporate class-based discussions, such as the development of science literacy (Wallace, 2004), but can also be used as a framework for characterising particular forms of usage of SNSs, and in particular Facebook. DePew (2011) describes the use of Facebook by three multilingual university students as a space to develop their English skills through the informal mixing of different written languages in an online setting. Lantz-Andersson, Vigmo, and Bowen (2013) report on the use of Facebook as a collaborative learning space for high school students, from four countries, learning English. Aaen and Dalsgaard (2016) document a study of Facebook groups created and managed by Danish high school students. Facebook can be useful for students in their social life as well as for academic purposes (Gafni & Deri, 2012). Here we are specifically interested in student-created Facebook groups, "characterised by a merging of the personal and institutional space, meaning that discourses from the normally separated spaces are included in the third space" (Aaen & Dalsgaard, 2016, p. 182).

This paper investigates and characterises public, student-created Facebook pages and groups relating to engineering at Deakin University. We use text analytics methods to visualise the content of the posts and comments to determine if they exhibit the distinctive characteristics proposed in the literature for student-created 'third space' Facebook groups.

Method

A ruling was obtained from the relevant institutional human research ethics committee (HREC) that the collection and use of publically accessible historical Facebook records in a manner that does not identify any individuals did not require formal ethics approval for research purposes. A search was undertaken to locate public Facebook pages and groups relating to engineering at Deakin University. The NCapture program (QSR International, 2017) is able to capture publicly available posts made by a specific Facebook account, as well as all follow-up comments associated with an original post. All of the publicly available posts and comments returned from NCapture queries of the identified Facebook pages and groups were captured. The NVivo program (QSR International, 2016) was used to convert the captured Facebook data into Microsoft Excel (Microsoft, 2013) spreadsheets. The Facebook data were graphed to visualise the frequency of posting activity over time. The text analytics software package KH Coder (Higuchi, 2016) was used to analyse and visualise the text content of the collected Facebook posts and comments to show the major themes present. KH Coder supports a range of text data analysis and visualisation methods – the one that we employ here is the multi-dimensional scaling (MDS) plot.

Text analytics typically requires pre-processing of the source text to achieve the best analysis result. Here we seek an overall characterisation of the content of public Facebook pages and groups relating to engineering at Deakin University, so all post text data were pooled. The data were exported in plain text format, converted to all lower case, and imported into KH Coder. Common English words and parts of speech, such as 'the', 'and', 'a', etc., add little to the analysis, and their relatively high frequency generally masks significant terms (Bolden & Moscarola, 2000). KH Coder supports the use of a stop word dictionary, in which common words to be ignored in the analysis may be specified. We used the default English stop word dictionary supplied with KH Coder. A second issue that can mask the significance of terms in text analytics is the presence of inflected and/or derived forms of words, for example, a root word such as 'sing' may also be present in the source text as 'sings', 'sang', 'singing', etc. Lemmatisation is a process to consolidate inflected and derived words into their root form, so that the underlying concept is accorded its due weighting based on frequency of occurrence (Bolden & Moscarola, 2000). We used the default English lemmatisation algorithm implemented by KH Coder.

MDS computes a measure of 'distance' between all pairs of text terms, and then seeks a lower dimensional representation of the terms, such that original distance values between all term pairs are displayed with the least possible error (Namey, Guest, Thairu, & Johnson, 2007). KH Coder supports a number of distance measures and dimensional reduction techniques – here we use the Jaccard distance measure (Hu & Liu, 2012) and the Classical distance scaling method for dimensional reduction (Abdi, 2007). Words/terms clustered close together in the resultant MDS visualisation are found more frequently close together in the source text, and may reveal key themes in the Facebook posts. Here we produce a two dimensional visualisation for ease of interpretation. Based on specifying the minimum frequency of occurrence of a term for inclusion in the MDS analysis and visualisation, terms appear as circles/bubbles in the plot, and the relative frequency of terms is indicated by the size of their bubble.

Results

Five public Facebook pages and six public Facebook groups relating to engineering at Deakin University were identified. Figure 1 presents, in the form of a heat map, the total Facebook activity (posts plus comments) for each of the pages and groups identified, in six monthly intervals, over the time period for which Facebook data were available. Based on examination of the ‘About’ information for the pages, and the listed ‘Admins’ for the groups, it was determined that Page1 was operated by academic staff, and that Group3 and Page4 were operated by ex-students (alumni). As the focus here was student-created Facebook pages and groups (Aaen & Dalsgaard, 2016), these three sets of data were removed from the analysis, leaving a consolidated data set of 1484 posts and comments, some of which dated back ten years, and comprising more than 51,400 words. Figure 2 presents the MDS visualisation of the text content of the 1484 posts and comments.

	Jul 07	Jan 08	Jul 08	Jan 09	Jul 09	Jan 10	Jul 10	Jan 11	Jul 11	Jan 12	Jul 12	Jan 13	Jul 13	Jan 14	Jul 14	Jan 15	Jul 15	Jan 16	Jul 16	Jan 17
Group1	0	0	0	0	0	0	0	0	0	0	0	5	0	0	8	1	0	1	0	0
Group2	12	1	1	1	1	2	1	3	2	7	5	8	17	27	44	25	9	10	28	10
Group3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11
Group4	0	0	0	0	0	0	0	0	0	7	23	58	56	47	20	3	3	38	38	25
Group5	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	2	0	0	0
Group6	0	0	3	276	285	48	7	6	2	0	0	0	0	0	0	0	0	0	0	0
Page1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	37	0	0	0
Page2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	9	12	26	20	6
Page3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	114	2
Page4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Page5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	9	12	26	20	6

Figure 1: Heat map of total Facebook activity for pages and groups in six monthly intervals

Discussion

There are some limitations to the data set used here. The search strategy used to locate candidate Facebook pages and groups was basic – a search based on the string “deakin engineering”. There almost certainly exist other pages and groups related to engineering at Deakin University not identified by the search, including those created by students. Within the full set of pages and groups identified by the search, there were several that were private, hence the content of those posts and comments was not accessible for inclusion in the analysis. With those limitations acknowledged, we can consider the results in detail.

Figure 1 shows highly variable levels of online activity between the different pages and groups, and within a given page or group, over the time period under consideration. Some have existed for an extended duration and have had at least some level of activity up until the time of the analysis. Others are more recent in their creation, and others still have come into life and apparently petered out during the time frame examined. It seems that student-created Facebook pages and groups do not automatically thrive or persist.

The MDS visualisation presented in Figure 2 includes an indication of clustering of terms using different bubble colouring. The clustering is based on the adjacency of terms when mapped to the two dimensional plot space, and is indicative only. KH Coder provides a key-word-in-context (KWIC) concordance feature that can identify the locations in the source post-and-comment text of phrases that contain one or more specified keywords within a specified distance of each other (Bolden & Moscarola, 2000).

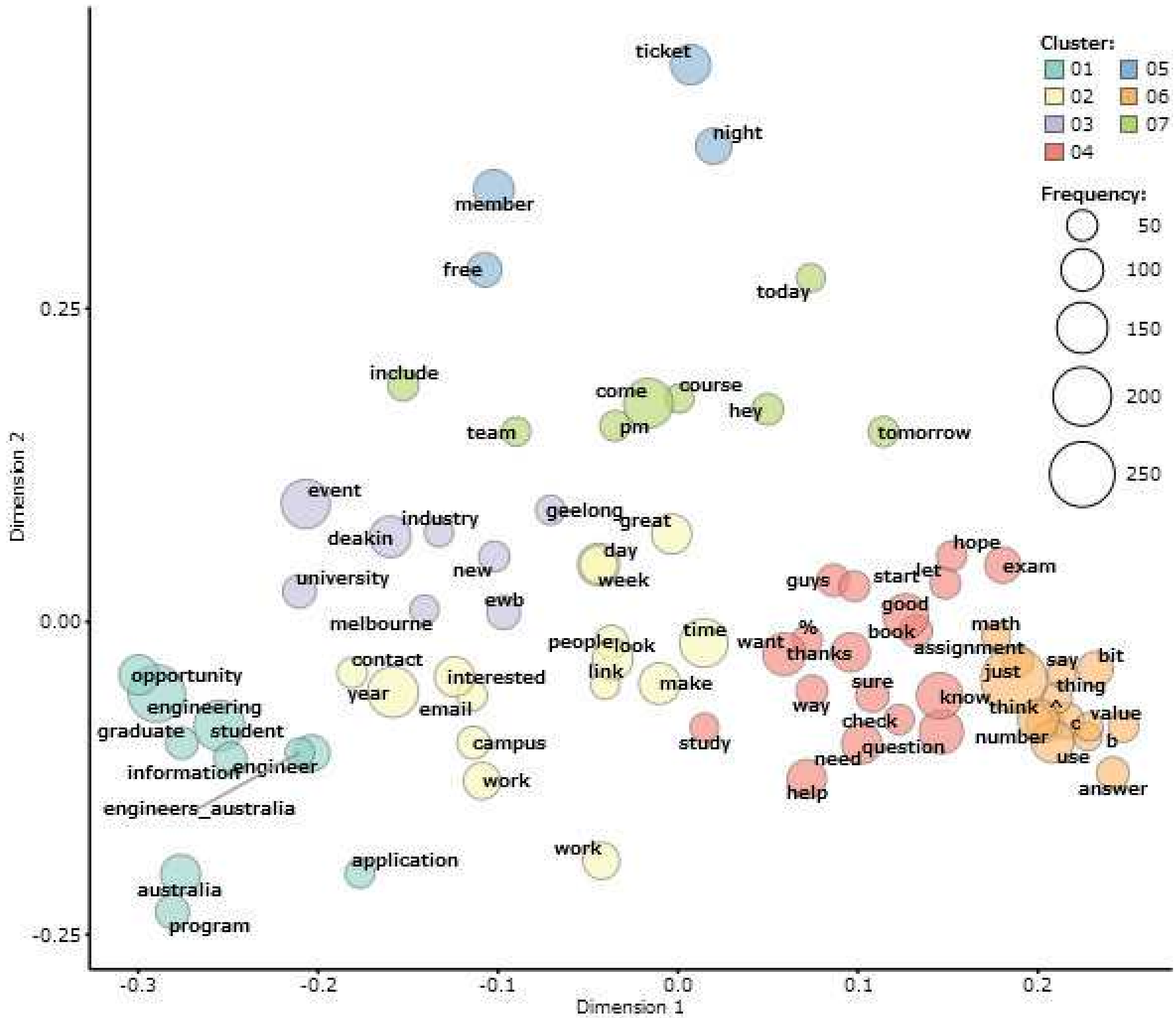

Figure 2: Multidimensional scaling plot of student Facebook posts and comments

The orange cluster at the lower right contains terms such as ‘number’, ‘bit’, value, ‘b’, ‘c’, ‘^’, ‘math’ and ‘answer’. The KWIC concordance was used to interrogate the original context of these terms, and it was found that they relate to discussions about specific assignment questions, including Boolean arithmetic problems, problems involving exponentiation (using the ^ operator), and mathematical problems with the variables b and c. The red cluster at the lower right contains terms such as ‘book’ (relating to the sourcing, quality and use of texts), ‘question’ (speculating on the likely content of exams, directions to, and comments about, set problems – students asking their peers for help with solutions was a minor component), ‘assignment’ (administrative processes, as well as some general discussion about specific questions) and ‘exam’ (strategies for preparation, comments on past papers, and public procrastination). The yellow cluster at the lower middle contains terms such as ‘campus’ (specifying the location of an event, or relating to the current or forecast location of the message poster, including off-campus for the significant number of Deakin University engineering students enrolled in that mode), ‘email’ (the poster giving their contact information) and ‘day/week/ year’ (for various temporal matters related to studies – timetables, course maps, etc.).

The aqua cluster at the lower left contains terms such as ‘engineers australia’ (referring to the campus chapter and Victoria Division matters), ‘opportunity’ (posts about volunteering, internship and other work openings) and ‘engineering’ (in a range of contexts including study, discipline, professional and graduate education). The purple cluster in the middle left contains terms such as ‘melbourne’ (where events will be held), ‘ewb’ (events, projects and other opportunities related to Engineers Without Borders) and ‘industry’ (mainly about the annual Deakin Engineering Society industry dinner). The green cluster in the centre contains terms such as 'today/tomorrow' (as notifications or reminders of events), 'come' (a reminder/exhortation to attend particular events) and 'team' (referring to group events, particularly EWB activities). The blue cluster at the top contains terms such as 'ticket/night/ member/ free' – being essentially the details for certain purely social events.

In their investigation of Danish high school student use of Facebook from a 'third space' perspective, Aaen and Dalsgaard (2016) found student-created groups contained the following types of content: "(1) social expressions, (2) social events outside of school, (3) social events on school, (4) academic content and subjects and (5) practical matters concerning school" (p. 183). In our investigation we observe largely the same categories of student communication. As Aaen and Dalsgaard (2016) concluded in a high school context, we also conclude here that student-created Facebook pages and groups related to engineering at Deakin University are being used as a social media third space. It is an online space that is different to, and operating in a space between, the 'first space' personal use of social media by students, and the 'second space' institutional use of social media to create online learning environments within the Facebook SNS. It is an online community where, "students blend the personal, social life with academic schoolwork in one space within the Facebook groups" (Aaen & Dalsgaard, 2016, p. 172).

Depending on the nature of the source text, it may be possible to attribute an ordinal or other meaning to the dimensions of the resultant MDS visualisation (Namey et al., 2007). Across the lower half of Figure 2, from right-to-left horizontally we see terms related to: specific assignment questions (orange); study skills and activities (red); course and campus issues (yellow); and, work and professional matters (cyan). Vertically, from bottom-to-top about the centre of Figure 2 we see terms related to: campus and course (yellow); activities related to engineering, but distinct from students' studies (purple); logistics for certain student group activities (green); and, promotion for purely social events (blue). Dimension 1 of the MDS plot can be interpreted as being related to the focus of student academic activities – ranging from very specific details at positive scores, through to big picture issues related to career and profession at negative scores. Dimension 2 of the MDS plot can be interpreted as being related to nature of student activities – ranging from study-related at negative scores, through purely social at positive scores.

In their current form, these student-created Facebook pages and groups appear to be serving a range of social and academic purposes, with some of them containing regular communication activity and persisting over an extended period. Based on strong student interest in, and adoption of, Facebook, some researchers have urged university educators to actively engage with students in the Facebook online space, to take advantage of this additional communication channel for educational purposes (Irwin et al., 2012; Roblyer et al., 2010). Others have urged caution for academic staff considering engaging with students in social media spaces, as it may be seen as intruding into the students' private domain (Hung & Yuen, 2010) or as violating the norms of student-staff relationships (McEwan, 2012), or, could lead to academics finding out 'too much information' about students, or students being placed in an awkward position due to the unequal power distribution (Karl & Peluchette, 2011). It is interesting to wonder if academic staff (or any other 'outsiders') were to make their presence known by actively posting into student-created social media spaces such as these, or even if it became known to students that there were lurking external observers of their proceedings, whether this would have any influence on the way that students operated in such social media third spaces. This project peered in from the outside to characterise the content passively, and did not actively engage with the users and their activity. While the work was conducted with HREC approval, is was also conducted using deontological ethical theory applied in a SNS context (Malesky & Peters, 2012) as a guiding principle for navigating the potentially ambiguous scenario presented by academic staff viewing student activity uninvited. Here our intent was to tread as lightly as possible to answer the research question, for example, using automated computer text analytics, rather than hand coding, not reproducing verbatim illustrative quotes from posts, etc. While academic staff can 'secretly' observe the proceedings of public student-created Facebook pages and groups in detail, in normal circumstances we recommend against this. It is unlikely that such student SNS use would be an assessable task, staff intrusion may disrupt an otherwise productive student online community, and, ultimately, students can make the space private anyway if they wish.

A question posed by the presence of social media third spaces is, if students are finding apparently educationally useful affordances in the use of such third spaces, and academic staff do not wish to actively intrude into their functioning, how can they never-the-less be factored in to the learning designs of units and courses in ways that are productive for student learning? Student use of Facebook for educational purposes is longstanding (Karl & Peluchette, 2011; Selwyn, 2007), so in one sense, academic staff might simply do nothing. There is evidence that student use of Facebook as a 'mirror space' to a formal LMS discussion forum can be more active and rich than the institutionally provided version (Karl & Peluchette, 2011). While academic staff promoting the possible use of SNSs by students for education purposes might not actually be news to most students, encouragement to students to 'bring back' into the formal LMS environment a summary of any relevant offsite discussions could be a productive way to capitalise on student-created SNS spaces.

Conclusion

The public Facebook pages and groups relating to engineering at Deakin University located in this study were largely student-created, and those exhibited the distinctive characteristics proposed in the literature for student-created 'third space' Facebook groups. Students were using these online spaces for discussing a range of academic, personal and social issues that were more or less related to their engineering studies. The focus of this paper has been on the Facebook SNS. The Twitter SNS also features in the related literature, and there exists an ever-expanding range of SNSs, each typically offering some new function that students might use in differing ways. Aaen and Dalsgaard (2016) noted that studies of voluntary student-created Facebook groups without participation from educators are underrepresented in the educational literature. With this research project we have made a modest contribution – both as a specific case study, and by offering a methodology that others interested in this area could use, including in the characterisation of other SNSs.

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Metacognition as a graduate attribute: Developing engineering employability with self and career literacy

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CONTEXT
Although engineering employability receives significant attention both nationally and internationally, there is little agreement about how employability should be defined or how it might be developed through an integrated approach. Definitions aside, student engineers need to prepare for careers that are increasingly unstable, mobile and self-directed. In the current climate, employability in engineering can no longer be defined as a job: it does not come with the graduation certificate or with accreditation and it requires constant work throughout the career lifecycle.

PURPOSE
This study positioned employability development as the cognitive and social development of student engineers as capable and informed individuals, professionals and social citizens. The study located employability development within the existing curriculum and sought to engage students as partners in their developmental journeys by creating a better understanding of students' thinking as student engineers.

APPROACH
The study employed a new measure of self and career literacy to develop personalised engineering profiles with 255 first-year engineering students. Students self-assessed their employability development using an online tool. Using the same process, educators will draw on students' self-assessments to rethink the design and delivery of initial engineering education, including composite forms of work-integrated-learning.

RESULTS
Early results indicate the value of a metacognitive approach to employability development. The measure revealed students' perceptions of their development as engineers. The inclusion of 'self' alongside 'career' revealed new insights on 'basic' career literacy, with students emphasising the need for high-level communication skills and a desire for work that has meaning and impact.

CONCLUSIONS
Employability development is a career-long concern in which higher education plays an intensive early role. Involving students in this process from the first year of studies has the potential for students to realise their individual roles as partners in the developmental process. The findings illustrate that the successful integration of engineering theory and practice requires students to become agentic partners in their personal development. For this to occur, educators need to understand students' perceived weaknesses and strengths, and areas in which they might be over-confident. The study reaffirms that it is insufficient for students to know how to think; they need a critical awareness and understanding of their thinking and learning processes. It is imperative, then, that metacognition forms the basis of an integrated engineering education.

KEYWORDS
Work integrated learning, graduate attributes, metacognition, employability

Introduction

This article reports early results from a study that fosters students' developmental agency through the creation and review of formative, personalised engineering profiles. Mindful that engineering graduates transition between roles and need to self-direct at least some of their work and learning, the study adopted a metacognitive view of employability on the basis. Peak body Engineering Australia (2014) agrees that only 62% of engineering graduates work in engineering-related roles and that the recruitment and retention of engineering students and graduates is a critical challenge in Australia (see also Male & Bennett, 2014; Tilli & Trevelyan, 2010). Further, the economic downturn has negatively impacted graduate employment and internship opportunities, with many engineers "forced to switch to other professions or leave the country in order to secure work" (Engineers Australia, 2014, p. 6).

Engineering educators need to prepare student engineers for more unstable, mobile and self-directed work than has traditionally been the case. Engineering is not alone: the number of part-time, casual and multiple job-holding workers has never been higher; neither has the prevalence of boundaryless careers (Arthur & Rousseau, 1996) that involve multiple employers, ignore traditional career progression, and traverse economic sectors.

Not surprisingly, current models of graduate employability often distinguish between job-getting and the ability to create and sustain work over time, including personal satisfaction and the importance of life-wide learning (cf. Yorke, 2006). Scholars are also responding to concerns that graduates lack the attitudes, emotional intelligence, inter- and intra-personal skills and metacognitive capacities to be successful in the labour market (Cumming, 2010).

Boundaryless careers (see Hall, 1976) in various forms are encountered by graduates from both generalist and professional programs and are variously pro-active (voluntary) and reactive (involuntary). In the case of graduate engineers, for example, a pro-active approach might include the adoption of short-term contracts or home-based work in order to meet caring commitments; a reactive approach might be adopted by a graduate who is unable to secure a traditional, full-time role and has to take whatever work is offered.

The implications for engineering education include developing student engineers' nascent personal epistemologies of self, career, learning and practice; self-concept and self-efficacy; and identity development. This requires students to be agentic, active learners and recognises the importance of self-knowledge and identity in learner engagement.

Purpose

The study reported here positioned employability development as the cognitive and social development of student engineers as capable and informed individuals, professionals and social citizens. The study located employability development within the existing curriculum and sought to engage students as partners in their developmental journeys. The team hopes that the initiative will help educators to embed employability thinking across the curriculum, help students to shape their future work and career, and create the datasets needed to understand students' thinking about their studies and their future lives and careers. This paper highlights students' first engagement with the study, at which time they created employability profiles using a trial version of the online tool. The paper describes the tool and its development and then presents and discusses student data derived from their profile development, focusing on students' responses to the concept of basic career literacy.

Approach and theoretical framework

First-year engineering students at a Western Australian university were invited to create a personalised employability profile using an online self-assessment; students were advised that completion of the tool would take 15 to 20 minutes. The 255 participating students received personalised profile reports followed by a workshop titled 'Me as an engineer'.

The study employed the Literacies for Life (L4L) measure (Bennett, in review), which is grounded in social cognitive theory and assesses five broad concepts:

- Self-management and decision-making relative to self and career (Lent et al., 2017), to self- and academic self-efficacy (Bandura, 1993; Byrne, Flood, & Griffin, 2014) and to self-esteem (Rosenberg, 1965);
- Professional identity construction in academic and future work (Mancini et al., 2015);
- Person-centred conceptualisations of self and employability including the citizen-self (Coetzee, 2014);
- Emotional intelligence (Brackett & Mayer, 2003); and
- The self-assessment of learner and graduate skills and attributes (Coetzee, 2014; Smith, Ferns and Russell, 2014).

The measure underpins a metacognitive model of employability in which employability is defined as "the ability to create and sustain meaningful work across the career lifespan" (Bennett, 2016). The model's six inter-related *Literacies for Life* combine to enhance employability and inform personal and professional development. The student version, illustrated at Figure 1, was shared with students as part of their profile and workshop.

Figure 1: Student (plain English) version of the Literacies for Life (L4) model

Students' online self-assessments involved completion of the L4L measure (134 items) and responses to five optional open response questions:

1. What do you think it takes to be a successful engineer? (Optional question)
2. Why did you choose to study engineering? (Optional question)
3. Have you made any career decisions at this point? (Optional question)
4. What do you want to achieve over your career? (Optional question)
5. Do you have any feedback on your degree program? (Optional question)

Items drawn from existing validated measures employed Likert scales ranging from 5- to 10-points. For the purposes of comparison, these were weighted to between 1 (not at all) and 6 (completely). Employability was then assessed by the six literacies in the L4L model. Exploratory factor analysis revealed that the literacies fit the data adequately; however, confirmatory factor analysis was not attempted with such a small number. Statistical analysis and validation of the measure will be undertaken at the end of 2017, with a bigger sample.

The length of open response questions ranged from three-word answers to several sentences. Textual data were coded and analysed for emergent themes, and quasi-quantification was applied as a means of summarising the material. This led to a final codebook and inclusion in the database (SPSS) for future analysis. Content analysis enabled the systematic, replicable compression of text into fewer content (Weber, 1990) and inspection of data for recurrent instances. Frequency counting was used where appropriate.

Results

This article reports results from the trial of the new measure. It focuses on students' perceptions of their basic literacy—their disciplinary skills and knowledge—and draws heavily on their open responses. Shown at Figure 2, basic literacy was the weakest of all the literacies for the first-year cohort. Given that first-year students have yet to build their disciplinary skills and knowledge, this is perhaps a predictable result; however, the L4L model is metacognitive in that it challenges students to 'think about their thinking' and to consider both self and career. Basic literacy incorporates 'disciplinary skills and knowledge' alongside 'communicating and interacting with other people' and 'using technologies for my work and learning', thus it is possible to look at student thinking across all three domains.

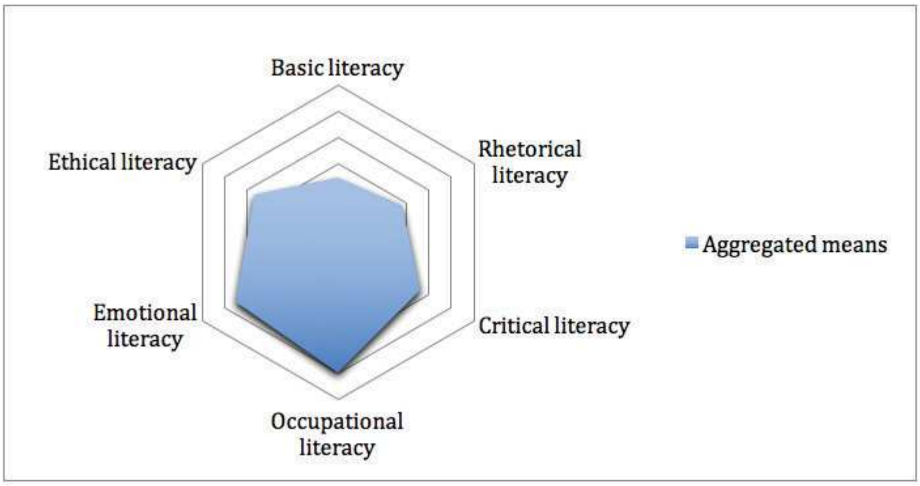

Figure 2: Students' aggregated results across the six L4L literacies

Within basic literacy, the four technology items attracted a mean score of 5.0/6. This indicated that students were fairly confident in their ability to use and learn technologies associated with their work and learning. In contrast, communications items averaged 3.7/6:

- I find it easy to get cooperation and support from others when working in a team. (*M* 3.4)
- I consult others and share my expertise and information. (*M* 3.9)
- I am able to build wide and effective networks of contacts to achieve my goals. (*M* 3.7)

The results indicate that the first-year student engineers were concerned aware of their ability to communicate effectively, which is at odds with the view that students are focused on the scientific or technicist aspects of their engineering education. Indeed, analysis of students' open responses reveals their belief that communication skills are a vital aspect of engineering practice. Responding to the question, "What do you think it takes to be a successful engineer?", 54 students emphasised the social aspects of engineering practice and just four students wrote only of technical or science aspects; only two students wrote exclusively about intelligence and high grades.

> *Successful engineers must be able to take initiative and think innovatively. They should be able to work well in a team and communicate their ideas effectively. I also believe a successful engineer is one that enjoys what they do.*

> *You should have good communication skills as you will be working in groups and will need to make good first impressions while working with other companies. You should be able to listen to other people's ideas and take criticism while proposing your own ideas. Compromising when needed as a client might disagree with what you have proposed.*

It was surprising to see the number of students who defined successful engineering work as personally meaningful, enjoyable, imaginative and/or having a social impact: for example,

> *To be an engineer is to think like a scientist and work like a tradesman. To be a successful engineer depends on whether you aim for income or self-worth; personally, I don't care about income so long as I have enough to live comfortably and pursue furthering myself and humanity.*

> *To be a successful engineer, you need an open mind that is not influenced by what is, but what things could become - a wide imagination and a head full of ideas with the commitment to learning and passion for the future.*

Eighteen students used the terms happiness or fulfilment and 23 students wrote about making a positive societal difference.

> *I want to have a meaningful career, one that I can look back on and say I made the right choices.*

> *Earn money while being happy with my job.*

> *Gain a well-paying job that I enjoy, one that I can sustain a family with. If I get the opportunity to better the world in some manner or form, that would be a great bonus as well.*

> *I want to become an expert in my field of work, while also upholding my personal interests, values and beliefs. I would also like to be able to provide security, both in a financial and emotional sense, to my family and those close to me. In addition, I believe firmly in making a lasting positive contribution to the community, so I therefore aspire to improve the world in some small way; ensuring environmental sustainability, and addressing matters of social justice and racial and gender equality. If I am only able to make a small change, I can still make a difference.*

The lowest mean basic literacy score related to students' self-awareness and their understanding of what they would learn within their program. These three items (listed below) attracted a mean score of only 3.3.

- I can identify personal weaknesses in need of further development. (*M* 3.3)
- I can articulate my personal strengths and how these can be deployed in my career. (*M* 3.4)
- I can identify the knowledge, abilities and transferable skills I will develop in my degree. (*M* 3.2)

The open question, 'Have you made any career decisions at this point?', prompts students to think about the rationale for their study choice and the relevance of that choice to their possible future lives and careers. This thinking is central to students' ability to identify the relevance and value of the knowledge, abilities and transferable skills developed within their degree programs. In this cohort of students, 42 students (16.4%) wrote about their 'career decision' to enrol in engineering. Many students were undecided about which engineering discipline to pursue, whilst other students felt that they were making progress: for example, "I am now choosing between 2 careers rather than 15!"

Among the 31 students who had not made any career decisions were those who had yet to give their future much thought and those who were thinking deeply about possible futures.

> *Not particularly as none have been qualified by financial or manual measures. The goal is to make enough money as an engineer and learn enough about engineering to start working on the issues our current world and its population face.*

For these students, indecision was voiced as a healthy aspect of self- and career exploration, even when indecision was prompted by less positive information.

> *Mining as well as oil and gas are a dying economy.*
>
> *I have accepted the fact that I might not necessarily receive a job in the field that I majored in.*
>
> *Yep, I really dislike maths. I'm going to try to avoid civil engineering.*

As expected, some students were unsure that they had made the right enrolment choice.

> *That if I choose to continue with engineering, which I'm unsure about, that I would want to do Chemical engineering.*
>
> *No, I still do not know which stream of engineering I want to go into, let alone if I'm going to continue doing engineering. I'm still not 100% certain about any of it.*

Students were given the opportunity to give feedback on their degree program, and the perceived relevance of learning featured strongly in their responses. For some students, the relevance was clear.

> *It is very good and gives me an idea on what being an engineer is like.*
>
> *Very well organised and seems to relate thoroughly to life after graduation.*

Other students, however, were struggling.

> *I feel there are several units which have little to no relevancy to what I wish to study in the future and it seems like a waste of resources, time and money.*
>
> *I believe some of the work we do in our degree is almost redundant and there is absolutely no guarantee to a position in the workforce after the completion of a degree.*

Discussion

Attrition among student and graduate engineers has led to concerns that students may enter engineering study without a sense of motivation and commitment, and without understanding the realities of either their degree program or engineering work (Male & Bennett, 2015). The link between relevance and learning is not new: Entwistle and Ramsden, for example, wrote over thirty years ago (1982) about students' tendency to adopt a surface or mechanical rote-learning approach towards material perceived as irrelevant to their future lives. Thus, relevance impacts not only the amount of relevant knowledge retained by students, but the level or depth of understanding they achieve.

More recently, scholars have examined the meaning and use of the term relevance. Writing about science, Stuckey, Hofstein, Mamlok-Naaman and Eilks (2013, p. 8) identified three dimensions with which science education can be seen as 'relevant': relevance for

1. preparing students for potential careers in science and engineering;
2. understanding scientific phenomena and coping with the challenges in a learner's life;
3. students becoming effective future citizens in the society in which they live.

The first of these three dimensions has particular bearing here, particularly because what might be perceived as relevant by curricular designers and educators may not appear so for students. Trevelyan & Tilli's (2008) longitudinal study of engineering practice highlights the stark differences between how students imagine engineering practice and what they experience in placements and as graduate engineers. The authors, for example, highlight that engineers spend only 10% of their time undertaking solitary technical work and around 60% of their time communicating directly with other people.

In the study reported here, first-year students emphasised the importance of communication skills when they responded to an open question about what it takes to be a 'successful' engineer. When completing the self-assessment measure, however, students assessed their personal communication skills as weak. Trevelyan (2011) has long argued that few engineering programs prepare students for the socio-technical aspects of engineering such as communication and working in teams. The fact that students recognised the importance of communication for engineering practice and recognised this weakness in themselves suggests that they would be accept explicit interventions to strengthen their skills. This would be further strengthened if the intervention was based on students' aspirations for the future.

Students were not confident about their ability to identify the knowledge, abilities and transferable skills they would develop through their degree studies. Although graduates go on to work in multiple engineering and non-engineering roles, there are core knowledges, abilities and skills that are transferable – communication being one of these. It would make sense to identify these for students so that regardless of their stage of decision-making or identity development, they can understand the potential relevance of what they are being asked to learn. As such, foundation years might consider positioning student learning more broadly even than the engineering disciplines.

Eighteen students used the terms happiness or fulfilment and 23 wrote about making a difference to the environment or to society. Students' responses indicate that many first-year students have internal and external motivations or drivers that inform their decision-making. These are not apparent when we ask why they chose engineering and hear "because I'm good at chemistry and maths". Following the lead that employability development has to be explicit, we might give students opportunities to discuss their passions, motivations and goals, and try to find links between these and what we ask them to learn.

Conclusion

This article concerned the self- and career thinking of 255 first-year engineering students at a single university; therefore, there is no attempt to generalise the findings. Data were derived from students' responses to an online self-assessment through which they created personalised career profiles. They were the first students to do this and it was too early in the study to make much of the quantitative data. With more participating students, however, it will be possible to identify characteristic trends across engineering disciplines and years of study, and to understand the thinking of students who belong to one or more equity groups.

The study recognised that employability in engineering can no longer be defined as a job and requires constant work. Whilst there is broad acceptance that engineering students need to form themselves for complex work *during* their studies, it is acknowledged that there are multiple challenges to accomplishing this task. Educators in particular can face multiple barriers such as out-dated industry knowledge, over-crowded curricula, modularised delivery models, research-focused career advancement, casualisation of the teaching workforce, and students who prefer their learning to be delivered as neat packages.

The L4L model emphasises a future-oriented epistemology of practice where possible future selves are internalised through effortful engagement with knowledge (including distributed learning) and action (experiential learning). Using the model, learning can be scaffolded so that learners purposefully engage with practice experiences and integrate them with their coursework. Initiatives such as these establish habits and practices that support the on-going development needed to sustain employability in the longer term. Combined, these factors highlight the need for a systematic and integrated approach to embedding effective employability development in engineering education.

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Links to the research and online resources

For the resources, self-assessment tool and more information, please visit the educator website (http://www.developingemployability.edu.au/). Student resources are hosted at (http://www.student.developingemployability.edu.au/).

Tangible Teaching Tools: The Use of Physical Computing Hardware in Schools

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SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

With the push for STEM education in recent years there has been significant growth in the popularity of "physical computing and robotics devices in educational settings" (Blikstein, 2013). With the introduction of the "digital technologies curriculum" (DTC) (Australian Curriculum and Assessment Reporting Authority [ACARA], 2015) there is a larger incentive for schools to consider the use of these tools. There are very few studies that examine the general usability of such programmable hardware devices from the perspective of non-expert users. This leaves teachers with little indication about the effectiveness of such hardware, with many relying on "word of mouth" when choosing between options in a crowded market.

PURPOSE

This study seeks to understand the experience of teachers who use physical computing hardware.

APPROACH

A qualitative approach is used to collect the data through a survey open to all teachers in Australia. The survey collects data on the subjects that are being taught, the year level and the programming experience of the teachers as well as the type of hardware that they use.

RESULTS

Physical computing hardware is an attractive option due to its perceived benefits for students and the digital technologies curriculum. There are many hardware options on the market, with a majority of teachers using more than one. However, there are many challenges associated with the use of physical computing. Teachers expressed issues such as time to learn, cost, curriculum development and technical issues.

CONCLUSIONS

For the digital technologies curriculum to be effective, the teachers must be at a suitable standard to teach it. This paper shows that the curriculum is likely to increase the number of teachers using physical computing hardware as part of the DTC. This is in part due to the perceived benefit to the students that this hardware has. This paper presents several issues that must be addressed for the curriculum to achieve its full scope such as the large number of hardware devices on the market, and the issues that teachers have expressed with the hardware.

KEYWORDS

STEM, Digital Curriculum, Schools

Introduction

The number of physical computing devices being used in schools has increased in the last few years. This has been aided by programs in other countries such as the UK's decision to lead the development of the BBC Micro:Bit which produced "1 million devices, enough for every 11-12 year old in the country" (Sentance, Waite, Hodges, MacLeod, & Yeomans, 2017). Australia is following this lead by implementing a nationwide "digital technologies curriculum" (DTC). The DTC was deployed in February of 2017 (Australian Curriculum and Assessment Reporting Authority [ACARA], 2015) and begins at the foundation level. It therefore introduces computer science concepts to many teachers who have not previously encountered them.

A popular method for teaching novice programming is to take a contextualized approach. "Contextualized computing education" is defined as the use of a consistent application or domain area which effectively covers the core areas of a computer science course (Rubio, Romero-Zaliz, Mañoso, & Angel, 2014). This is an attractive idea in computer science education because instead of writing an abstract program, students can learn programming concepts through making a game or animating a story. Increasing the relevance of computer science education to students lives has been suggested as an effective strategy for making students more interested in computing (Black et al., 2013).

'Physical computing' is a specific subset of this contextualised approach to computing education. Instead of programming concepts existing only within the confines of the computer, robots or other programmable hardware are used to bring these ideas into the real world. There are many physical computing devices designed for education. Blikstein (2013) conducted a meta-analysis of the history and current market of physical computing hardware. He showed that although physical computing hardware has been developed since the 1980's there exists little consensus about the best tools to be used for computer science education.

Physical computing hardware is not required by the DTC. However, there are a large number of devices on the market that advertise themselves as an "easy to use introduction to programming". These include hardware such as Arduino ("Arduino Education," 2017) and Bee-Bot ("Bee-Bot," 2016). Physical computing hardware is also prevalent in the supporting documentation for the DTC. There are three case studies for digital technologies in primary school on the Victorian government's "DigiPubs" website (Department of Education and Training, 2017). All three case-studies feature students interacting with physical computing devices.

It is likely that the advertising of physical computing hardware in the materials supporting the DTC will encourage teachers to use physical computing hardware. This will have an impact on the teachers implementing the curriculum who have never taught digital technology related subjects before.

This paper gives an overview of the state of the physical computing hardware market in Australia and discusses the challenges that teachers have faced when implementing physical computing classrooms. It also suggests some areas in which support can be provided to teachers without the skills needed to teach this curriculum.

Methodology

Context and participants

A wide variety of teachers were invited to complete an anonymous survey. A Facebook page was created to allow teachers to share the survey with colleagues to further extend the pool of teachers completing the questionnaire. An invitation to complete the survey was posted to five separate teacher groups. These were: Awesome Science Teachers (now Awesome

NSW Science Teachers), Australian Teachers Interested in STEM and STEAM, Australian Primary Teachers, Australian Primary Ed Teachers and Australian P-12 Teachers.

Additionally, an email list was developed based on schools who had participated in the Robocup Junior and Young ICT Explorers competitions. Public email addresses were obtained from the websites of schools who had participated. This list consists of 175 distinct email addresses.

Data collection and data analysis

The primary data consists of a survey filled out by teachers. The survey collected information about teachers who both use and don't use programming hardware. A total of 36 teachers completed the survey. 14 respondents were recruited via Facebook. Of the 171 email addresses, which were included in the mailing list, 22 completed surveys were submitted (a response rate of 12.9%). This number is possibly inflated as the email addresses used were the school administration email. This does not indicate how many teachers from each school submitted a survey response. The lack of identical responses suggests that only a single teacher from each school participated.

The survey was divided into two sections, one for background information on the teachers and the second collecting information about their experiences with physical computing hardware in the classroom.

The first section consisted of six questions collecting background information on the teacher. These questions include which state they teach in, the year level that they teach, what subjects they teach, the size of the class that they typically teach and self-assessments of their general technology usage and programming skill level.

The questions in the second section were related to the experiences that these teachers have had using the hardware. This section was only completed by teachers who use physical computing hardware in the classroom. They were asked:

- Why did you introduce educational hardware kits into your classroom?
- What hardware system(s) do you currently use?
- Why did you decide this hardware kit?
- How beneficial has it been to your students?
- How easy has it been to use?
- How well has it met your educational goals?
- What are the challenges you have faced in using this hardware?

Limitations of the study

It is important to note that the method of study could have introduced potential biases to the results. The respondents are self-selecting which could result in respondents who are the most keenly engaged. Furthermore, the selected target group was intended to be as wide as possible, however the response rate from the Facebook advertisement was low. This means that approximately two thirds of the respondents belonged to schools which were known to have technology programs due to their inclusion in either the Robocup Junior or the Young ICT Explorers competitions.

Nevertheless, the results provide an insight to these teachers experience with the hardware that they use to teach computer science skills in the classroom.

Results

A total of 36 responses to the survey were received. Of these, 23 had introduced physical computing hardware in their classrooms and 13 who do not use hardware in the classroom.

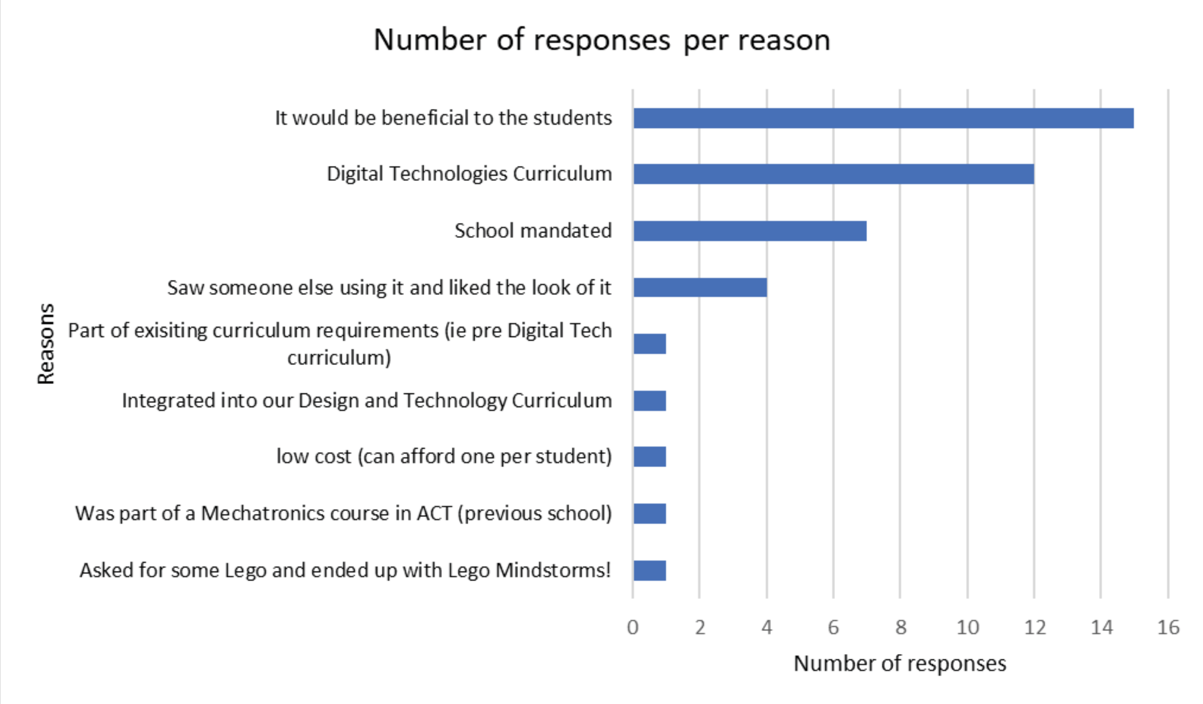

Figure 1: Reasons for the introduction of physical computing hardware

Figure 1 shows the reasons that teachers gave for deciding to introduce physical computing hardware into their classrooms. The two main reasons given were that it would be beneficial to the students and due to the DTC.

The most common reason for introducing hardware into the classroom was that it would be beneficial to the students. This was mentioned by teachers of all programming experience levels, from novice to expert. The two teachers in the sample who had never programmed before both mentioned this as their only reason for introducing hardware. This indicates that even for teachers with little programming experience, if they believe that students will benefit from the introduction of hardware they will implement it.

The second most common reason was the DTC. This shows that even in the first six months that it has been mandatory, it has factored into the decision making of teachers. The combination of the perceived benefit to students and the DTC support the assumption that the DTC will increase the demand for physical computing hardware in Australian schools.

The presence of the 7 other reasons given for the introduction of hardware show that teachers decision making is varied. The variety of reasons given provide further evidence for the assumption that the demand for physical computing in schools will continue to grow.

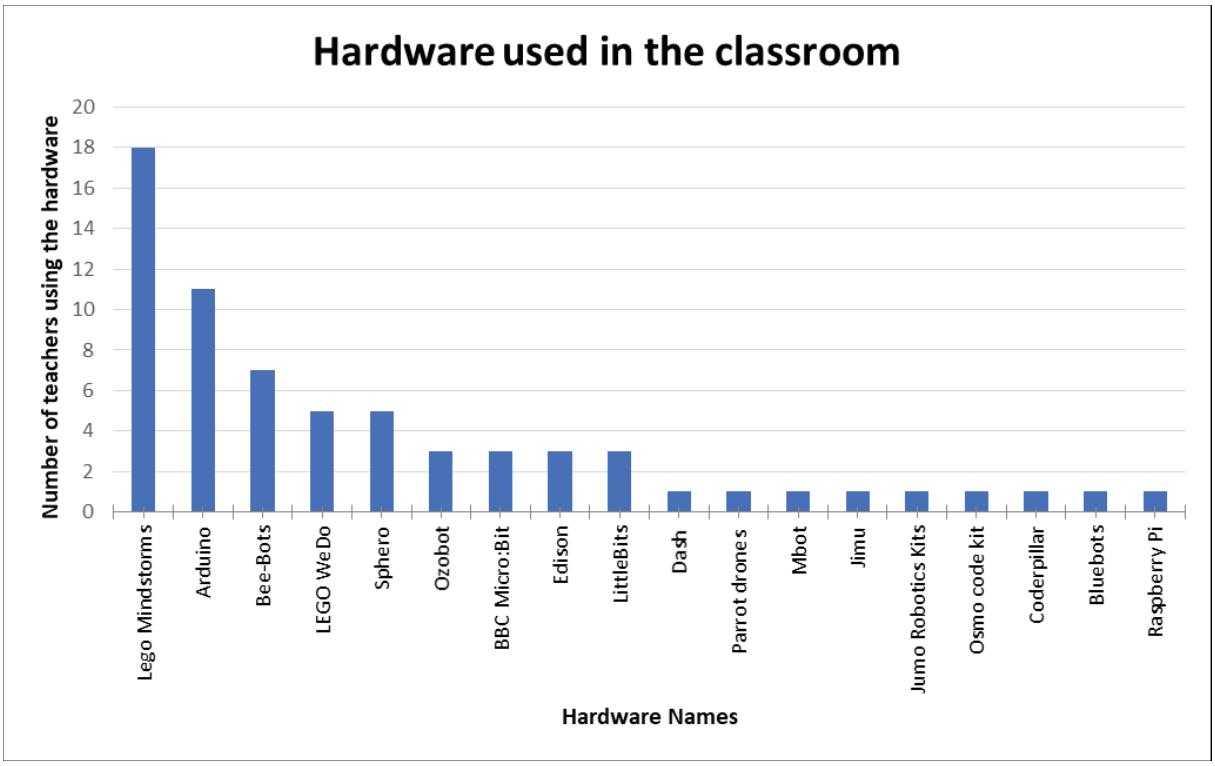

Figure 2: Physical computing hardware teachers have used in the classroom

Figure 2 shows the hardware that teachers have used in the classroom. In total, the 23 teachers have used 18 different hardware kits between them. This shows that there is a very competitive and fractured market in educational hardware. The large number of kits used by such a small group of respondents suggests that there is no real consensus on the best hardware that can be used. Lego Mindstorms was by far the most popular (but this is possibly due to the survey being sent to schools who had participated in RoboCup Jr, where it was the standardised platform). Arduino was also widely used, possibly due to its popularity amongst engineers. For many of the other kits however, there was not much overlap between the teachers. There were 9 different types of hardware that were only used by a single teacher.

The number of different hardware kits mentioned by the small sample size shows that there are many teachers using more than one type of hardware. 65% of respondents were using more than one type of hardware and 39% of all respondents were using more than 4 types of hardware. This shows that there is a lot of experimentation occurring within the market to try and find the best hardware for the classroom.

Challenges

Respondents were asked to identify the challenges that they have faced in using physical computing hardware in their classrooms. These responses were analysed and categorised to determine the themes that were present. The challenges that the teachers faced fell into four categories: cost, time, curriculum and technical.

'Cost' relates to the actual cost of the hardware that must be purchased. This came up several times in the responses. Interestingly, when this was mentioned as an answer to this question it was always in relation to the upgrade of hardware rather than the purchase of new hardware. Two teachers had issues with the Lego Mindstorms NXT kits because the software that was developed for this hardware no longer supports new computers and iPads.

One school was not able to afford the upgraded robots; therefore, they had to deal with the software discrepancies that exist when using new software for old hardware.

school uses NXT robots, cannot afford new ones, EV3 is not 100% backwards compatible.

A second school upgraded the hardware because the previously developed software did not support the iPads the students were using.

Lego kits needed to be updated as older kits weren't compatible with students BYOD ipads.

The cost of hardware necessitates a long upgrade cycle to ensure that schools get the most out of their purchased hardware. The presence of backwards compatibility, such as the limited compatibility included in the Mindstorms EV3 software (Lego, 2017), can help extend the useful lifespan of hardware. However, the responses indicate that this can cause more issues.

'Time' relates to the time that teachers must put into setting up the new hardware for their classroom. This is important because many teachers work long hours. In 2016, the average teacher worked 52.3 hours (Weldon & Ingvarson, 2016) so the amount of time that hardware takes to setup, learn and teach with will impact on its effectiveness. "Steep learning curve" and the time taken to learn new hardware was a common complaint. These comments show the impact that ease of use has on the usefulness of devices for education. Given teachers' time constraints, the longer it takes to learn to use hardware, the more difficult it will be to introduce it to the classroom.

For the LEGO Mindstorms, a lack of time to play and experiment with them is the major challenge. I also need an expert to help me get started.

Steep learning curve…

Teaching myself to use them

Time limitations, facilities and storage

Edison's have taken a little while to get to grips with more complex coding…

The third theme that emerged from the comments was 'curriculum'. A number of teachers commented on the "availability of curriculum resources" that are of a high quality and aimed at the correct level for students. Often there existed a gap for teachers between the sample tasks that are included with physical computing hardware and what the students wish to do.

Access to quality project activities to fill the gap between the sample tasks and student desires while teaching them the essential programming skills. Most activities are too low level (k-6), are plug and play without the programming, or are for proprietary gear.

Access to good quality guides for students to follow that do not propagate misconceptions related to electricity.

diverse ability of students

When teachers are in a position where they don't have access to good quality resources for the subjects that they are teaching, they are forced to create them themselves. This has two effects. Firstly, teachers without the knowledge to create these resources are likely to struggle to teach adequately. Secondly, the teachers who do have the knowledge and experience to develop their own resources must do so on their own time. We have already discussed that teachers feel as though they don't have the time to get started with the hardware; developing the resources adds extra time to this process.

One teacher raised the issue that hardware can add an extra layer of complexity to the concepts and therefore increase the difficulty of curriculum design.

Designing curriculum around the software and hardware interface - sometimes concepts required for the hardware are not easy to understand at the level where students are at, although they are still capable of using it and playing with it.

Another curriculum issue was the combination of project based learning and more traditional teaching styles. It is up to the teacher to decide how to balance these two ideas to ensure that the students get the most out of using the hardware. (Holmberg, 2017; Hussain, Fergus, Al-Jumeily, Pich, & Hind, 2015; Jin, Haynie, & Kearns, 2016)

Balancing project based learning and direct instruction

I think it's important that educational kits be more than expensive toys. Students should be able to create and solve problems with them. That's why I prefer kits like Lego over kits like Sphere.

Previous studies have shown that “young learners are often distracted by the physical hardware” (Jin et al., 2016). By increasing the number of distracting elements in the classroom, the teacher must be prepared to control the class to keep them on track.

The students seem to get sidetracked building the Lego and don't spend as much time on the coding.

The final category was ’technical issues’. This categorises issues that can only occur when using a physical piece of hardware. The other three categories can all be applied to programming applications on a computer. These are issues related to the upkeep and maintenance of the hardware. Some teachers had issues with parts continually going missing.

Losing parts, flat batteries, time taken in building robots rather than programming them (although students generally enjoy building).

Parts going missing!

Other teachers had more general technical problems with the hardware. The lack of specifics offered by the respondents suggests that a large number of problems have been encountered.

Continual technical problems

Arduinos and coding and different shields.

Troubleshooting the devices to allow them to work.

A number of teachers mentioned that they were not able to supply enough devices for every student. This is a combination between the cost and technical issues. If the cost were lower they might be able to purchase enough hardware for each individual student. As they aren’t able to do this, the hardware must be used by many students.

Maintaining the equipment when it is used by multiple classes

Another teacher raised the point that when the students have to share between classes they are limited in the creativeness that they can influence on the designs.

Having to share kits between classes means students usually needed to stick to standard robots (using Mindstorms) rather than spend time building their own creations.

Having enough devices for the children to use.

The results have shown that there is a real need for tools that can help teachers choose between the available hardware options. We propose a website that hosts a survey for teachers to self evaluate the hardware devices that they use. This can provide an evolving resource for new teachers to be able to find hardware that suits their specific situation. A prototype has been developed and is available at http://jmss.it/physicalcomputing.

Conclusion

The DTC ensures that students are being equipped for a digital future. For the curriculum to be effective, the teachers must be at a suitable standard to teach it. This paper shows that the curriculum is likely to increase the number of teachers using physical computing hardware as part of the DTC. This is due to the perceived benefit to the students that this hardware has, combined with the prevalence of physical computing in the digital technology curriculum resources. This paper presents several issues that must be addressed for the curriculum to achieve its full scope. Firstly, the large number of hardware devices on the market present a challenge for teachers to be able to choose the best hardware for the job. Secondly, the teachers currently using hardware in their classrooms have described issues that they are experiencing. These issues can be categorised as time, ease of use, cost, curriculum and technical. These issues identified by the early adopters must be addressed before subsequent groups can begin to use this hardware effectively.

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Introducing TRIZ Heuristics to Students in NZ Diploma in Engineering

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SESSION S2: Educating The Edisons Of The 21st Century

CONTEXT Institutes of Engineers all over the world have identified problem solving and creativity as vital skills for engineering graduates to possess in the 21st Century (e.g. Engineers Australia, 2011; National Academy of Engineering, 2004). Recent Deloitte report specifically mentioned these skills as increasingly important for success of Australian businesses by 2030 (Deloitte, 2017). Research evidence of the ability of engineering programs to nurture creative graduates is inconclusive. Some authors reported on failures of current engineering programs to enhance students' creativity (e.g. Daly, Mosyjowski, & Seifert, 2014; Steiner et al., 2011).

Acquisition of professional problem solving skills is one of the main aims of the New Zealand Diploma in Engineering (NZDE). With emphasis on holistic approach in engineering education, introduction of the Theory of Inventive Problem Solving (TRIZ) heuristics could help students to be better prepared for cognitive challenges.

PURPOSE To establish whether the educational materials provided by the TRIZ Repository of thinking heuristics (OLT Fellowship, 2016) are suitable for self-learning of NZDE students.

APPROACH Sixty NZDE students from mechanical, electrical and civil strands participated in TRIZ workshops in semester 1 2017. Then they were directed to the repository of TRIZ educational materials and were asked to complete an online survey. All students were encouraged to apply TRIZ heuristics in the Engineering Project paper. The paper analyses students' feedback and investigates possible integration of the TRIZ into the NZDE program.

RESULTS A set of TRIZ tutorials and workshops with NZDE students at TOIT (Bay of Plenty, NZ) has revealed their genuine interest shown through surveys and discussions. The majority of students have expressed a clear need for learning such problem solving tools during their study NZDE. A large percentage of students have shown self-motivation to learning TRIZ through the online resources offered by the TRIZ Repository. Most of the students assessed self-learning resources offered by the repository of TRIZ educational materials as suiting their learning and their future needs. Their survey responses suggest that the heuristics they have learnt just over a couple of hours have not only helped them in generating more ideas for their projects, but also influenced the way they solve problems.

CONCLUSIONS Introduction of the problem solving techniques such as TRIZ into engineering education has a longstanding need, which is now not just appreciated by the professionals but the students themselves. The feedback from the NZDE study participants indicates the usefulness of the TRIZ heuristics for the NZDE program and especially for the Engineering Project course. It is recommended to introduce thinking heuristics to students early in their engineering study and to develop appropriate summative assessment to evaluate how well they have learnt and used of these heuristics in project work.

KEYWORDS Engineering education, TRIZ, NZDE, creativity, Engineering Project.

Introduction

Institutes of Engineers all over the world have identified problem solving and creativity as vital skills for engineering graduates to possess in the 21st Century (ENAEE, 2015; Engineering Council, 2013; Engineers Australia, 2011; National Academy of Engineering, 2004). Recent reports of Deloitte and the Australian Government specifically mentioned these skills as increasingly important for success of Australian businesses by 2030 (Deloitte, 2017; Department of Emloyment, 2016). Over 800 CEOs of international corporations that were interviewed by IBM supported the importance of creativity in achieving company goals. They suggested that in order to survive and prosper in the world of disruption companies need to accelerate innovation (IBM Institute for Business Value, 2016).

Research evidence on the ability of engineering programs to nurture creative graduates is inconclusive. Some authors reported on failures of current engineering programs to enhance students' creativity (Daly et al., 2014; Sola, Hoekstra, Fiore, & McCauley, 2017; Steiner et al., 2011). On the other hand, there were reports on successes in enhancing problem solving and creativity skills of engineering students (Belski, Baglin, & Harlim, 2013; Hugh et al., 2007). This study is focused on development of creative problem solving skills in engineering diploma students from New Zealand.

The New Zealand Diploma in Engineering (NZDE) is a two-year full time program. It is often considered as the first step in tertiary engineering education. Institutes of Technology are the main providers of the engineering diplomas in New Zealand. They offer diploma programs in four major engineering fields: civil, mechanical, electrical and electronic. These programs must adhere with the Dublin accord of the International Engineering Alliance (International Engineering Alliance, 2016) as well as with New Zealand National Curriculum for engineering diplomas (New Zealand Board of Engineering Diplomas, 2016). In accordance with the National Curriculum, graduates of the Institutes of Technology are expected to develop competencies allowing them to solve well-defined engineering problems (p.45). This, among other skills, requires proficiency in problem identification and problem analysis (p.46).

Significant percentage of the NZDE graduates continue their study at universities in New Zealand and abroad in order to complete a degree of the Bachelor of Engineering (Washington accord) or the Bachelor of Engineering Technology (Sydney accord). Usually NZDE graduates enrol directly in the second year of a bachelor degree. Most universities offer NZDE graduates cross-credits for up to one and a half years of bachelor studies.

The NZDE curriculum is well compiled and includes sufficient volume of engineering theory and engineering practice. At the same time, it does not explicitly address the enhancement of some soft skills, such as problem solving, problem identification and evaluation, risk management, etc. It is anticipated that these soft skills are gained naturally as a result of two years of study. This does not necessarily happen that way. Indeed, some students are more natural learners and are able to acquire problem-solving skills over two years of the diploma study; other students that require extra teaching support may graduate with underdeveloped soft skills. The latter cohort would be much better of if simple heuristics that they can apply in problem solving were taught to them explicitly. Taking into account the constraints of the existing NZDE curriculum, it would be ideal to embed simple problem-solving heuristics into existing NZDE courses. Also, it would be advantageous to utilise existing educational materials that have already been developed by expert problem solvers and that can be used for free.

This study investigates the suitability of educational materials that are offered by the repository of thinking heuristics (TRIZ Repository) developed by the fellowship team led by Belski (OLT Fellowship, 2016) for embedding into the NZDE curriculum. These educational materials have been provided under the Creative Commons licence and could be used freely by both teachers and students. During semester 1 of 2017 four heuristics that belong to the Theory of Invention Problem Solving (TRIZ) were promoted by the fellowship repository.

Three of these heuristics looked suiting the needs of the diploma students. Therefore it was decided to formally introduce to the students the heuristics of *Size-Time-Cost Operator* that guides problem framing and reframing, *Notion of the Ideal Ultimate Result* (IUR) that helps to 'envisage' the future, and *8 Fields of MATCEMIB* that makes idea generation fun.

Methodology

Sixty students enrolled in various diploma programs at the TOI-OHOMAI Institute of Technology (TOIT) were introduced to three TRIZ heuristics in semester 1 of 2017. Twenty-seven students were in their last year of diploma study. Twenty-three students were in their first year of NZDE. Ten student participants have been studying on a part-time basis. They were with TOIT for over two years. The TOIT diploma students come from diverse backgrounds. The students that participated in this study were a mix of school leavers and mature adults. About 20% of them were international students, who mainly came from India.

It was anticipated that learning TRIZ heuristics would help students to excel in courses that are focused on development of soft skills, like Planning, Time and Engineering Management, Creativity, Control and etc. Furthermore, TRIZ problem-solving heuristics could be very useful in completing the Engineering Project that is carried out in the last semester of the diploma study (in semester 2 of 2017 for the cohort of 27 students). The aim of the Engineering Project course explicitly mentions the problem-solving skills: *"To apply knowledge and problem-solving skills to plan and complete an engineering project relevant to the discipline strand studied…"* (New Zealand Board of Engineering Diplomas, 2016, p. 133).

Final Projects of the 27 graduating students represented TOIT diploma programs from all four major engineering fields and were reasonably complex. The following are some of the project titles that the graduating students were involved in: "Simplifying existing drink dispenser", "Design of a model gantry crane", "Design of a prototype conveyor system", "Design of an automated weighting and data recording system for the fish processing plant", "Sun tracking system for solar power", "Developing a PID controlled system for variable speed drive".

Three class sessions on TRIZ heuristics were conducted in order to engage students in enhancing their thinking skills. In the first session, students enrolled in the last year of study were introduced to TRIZ heuristics of *8 Fields of MATCEMIB* and *Size-Time-Cost Operator*. At the beginning of the class they were asked to suggest as many ideas as they could for the ways and the means of protecting buildings from termites. Then, as recommended by the TRIZ Repository, they watched the *8 Fields of MATCEMIB* video and tried to generate as many ideas as possible for the termite protection. Towards the end of this session students were also briefed on the *Size-Time-Cost Operator* heuristic.

The second session was conducted for the students of mechanical engineering that represented both years of NZDE. This session was devoted to the *Notion of the Ideal Ultimate Result* (IUR). Students watched the IUR video and participated in a discussion on the application of this heuristic in their TOIT projects.

The third session was conducted for the students enrolled in the first year of diploma studies. It introduced students to the heuristics of *8 Fields of MATCEMIB* and *Size-Time-Cost Operator* and was conducted in a similar way to the first session.

At the end of each session it was recommended that students devote an hour or two of their personal study time to look through educational materials, papers and case studies offered by the TRIZ Repository. Students in their final year of study were encouraged to use TRIZ heuristics in preparation for their Engineering Project course. They were given permission to incorporate the pdf solution templates (that are available from the TRIZ Repository) for any heuristic they will use into their final Project Report. All students were asked to consider participation in the *Edisons21 Creativity Challenge* that required a formal submission of a report on the outcomes of usage of the heuristics to the fellowship team (OLT Fellowship, 2016).

At the end of a semester students were asked to participate in a survey and to share their experiences in learning TRIZ heuristics. This web-based survey was built and administered by the team that has been developing the TRIZ Repository. The survey consisted of around 60 questions that covered general information about students, their perceptions on their problem solving abilities, their opinions on the quality of self-educational materials available at the fellowship repository and suitability of these materials for their learning. Twenty-one students completed the survey.

Results

Face-to-face sessions

After watching the video on the *8 Fields of MATCEMIB* heuristic, participants of the first and the third sessions proposed many more ideas for building protection against termites. In essence the number of solution ideas doubled as a result of them watching the video. While discussing individual solution ideas, some students revealed that they excluded some ideas that were similar to that generated after they watched the video from the list of possible solutions they have recorded originally, prior to watching the video. Many of the students said that they were simply uncertain of safety and environmental impact of these solution ideas, so they decided to keep them private.

Student reaction to TRIZ heuristics varied from full support to absence of any interest. Some were very exited and said that they will try applying the heuristics to their own “world saving” inventions; some were simply bored. Students from mechanical and electrical streams were much more engaged in class activities that that of the civil discipline. Mature students were much more interested than recent school leavers and were willing to immediately apply TRIZ heuristics to solve their problems.

Survey results

Quantitative outcomes

Twenty participants of the survey were male; one was female. Seven identified themselves as the first year students, 12 – as the second year students. Two participants did not offer their year of enrolment. Six students were younger than 20 years of age. Eleven were between 20 and 30 years old. Two students were in each of the 31 to 40 and 41 to 50 age brackets.

Students were certain in soundness of their problem-solving skills. Table 1 depicts their responses to the survey questions that were related to their problem-solving abilities.

Table 1: Student opinions on their problem-solving abilities. All questions used the Likert scale of 5 (1 – strongly disagree; 5 – strongly agree)

	I am very good at problem solving	I am unable to tackle unfamiliar problems	So far, I have resolved every problem I faced	I am certain that I am able to resolve any problem I will face
Mean	4.00	2.70	3.40	3.65
SD	0.649	0.865	1.095	0.875

Survey participants positively evaluated the quality of educational materials offered by the TRIZ Repository. Table 2 presents student opinions on the usefulness of materials in general and on the effectiveness of each of the components: a short Video, a Solution Template, a Web Tool and a Cheat Sheet.

Table 2: Student opinions on the usefulness of educational materials offered by the TRIZ Repository. All questions used the Likert scale of 5 (1 – strongly disagree; 5 – strongly agree)

	Educational materials for self-learning TRIZ heuristics made it easy for me to learn thinking heuristics	A short Video that explained the way to apply a heuristic was very helpful in learning the heuristic	A Solution Template that guided me in applying a heuristic for the first time was very helpful in learning the heuristic	A Web Tool that guided me in applying a heuristic for the first time was very helpful in learning the heuristic	A Cheat Sheet was very helpful in applying the heuristic
Mean	4.00	4.07	4.07	3.69	4.00
SD	0.365	0.594	0.458	0.751	0.816

Student responses to questions related to the influence of the heuristics on their projects and on their approach to problem solving were also positive and are shown in Table 3.

Table 3: Student opinions on the influence of TRIZ heuristics. All questions used the Likert scale of 5 (1 – strongly disagree; 5 – strongly agree)

	I believe the heuristic(s) I have learnt helped me to understand my problem much more clearly	I believe the heuristic(s) I have learnt helped me to generate more ideas for my project	Learning the heuristics changed a way I resolve problems
Mean	4.00	4.06	3.87
SD	0.365	0.443	0.500

Qualitative outcomes

Survey participants were asked to explain the reasons for some of their answers to the above-mentioned questions and also to suggest how the TRIZ Repository can be improved. The following are some student comments.

Comments related to the question "*I believe the heuristic(s) I have learnt helped me to understand my problem much more clearly*":

> *"It makes you think in different ways you would not usually think." "Because I was able to approach the problem from many different angles". "Well the areas I am lacking or struggling to find ideas has been helped by the heuristic". "It helped narrow the problem down into categories that have viable solutions". "Being able to see problems from more than one angle." "Helped to look at the bigger picture".*

Comments related to the question "*I believe the heuristic(s) I have learnt helped me to generate more ideas for my project*":

> *"Heuristic helped me to generate more ideas for my project "."I'm very experienced with creative problem solving and lateral thinking, accompanied by industry knowledge. Applying heuristics has reinforced my current methodology and generated few new ideas." "Using the size-time-cost helped me generate realistic ideas even when thinking if money was not an issue. By thinking in such a wide point of view can create ideas that can then be broken down into more feasible goals."*

Comments related to the question "*Learning the heuristics changed a way I resolve problems*":

> *"For the most part I already applied a lot of these subconsciously however I do approach the way I solve problems slightly differently." "Because its totally different to my thinking". "Heuristics give me a distinctive view point towards a problem". "Taking time to analyse the problem and think of things that can be resolved with the given time or resources available, or what issues need to be solved in a different perspective".*

Most of the survey participants were overall happy with the materials offered by the TRIZ Repository and suggested minor improvements. One student explicitly suggested the TRIZ heuristics offered by the Fellowship Repository to be promoted to educators:

> *"Please do some adverticements on websites and mail [information on the TRIZ Repository] to tutors and students as well …"*

Discussion

Student opinions presented in Table 1 indicate that the participants were very confident in their problem-solving abilities. Actually, the Diploma students judged their problem-solving skills to be on the par or even exceeding that of the students enrolled in Engineering Degrees in Australia that were evaluated in the past (Belski et al., 2013; Steiner et al., 2011). Perceptions of own problem-solving abilities of the NZDE students differed the most from that of 325 students enrolled in engineering Bachelor degrees that were surveyed by Steiner et al. (2011). The responses of these two student cohorts to the question "*So far, I have resolved every problem I faced*" exhibited the largest discrepancy. As shown in Table 1, the NZDE students evaluated their past problem solving achievements slightly positively (Mean = 3.4/5). Students enrolled in engineering degrees, on the other hand, were neutral (Mean = 3.0/5). It must be noted that the students surveyed by Steiner *et al.* did not study thinking heuristics. The opinions of the NZDE students came out of the survey that was administered after they have learnt TRIZ heuristics from the TRIZ Repository. They were not surveyed prior to the introduction of the heuristics. Therefore it is impossible to establish whether the simple TRIZ heuristics the NZDE students have learnt made any influence on their problem-solving self-efficacy. Such positive influence of TRIZ heuristics on problem solving self-efficacy is possible and has been reported by Belski *et al.* (2013). The change in problem solving self-efficacy of 93 students as a result of learning TRIZ heuristics in a one-semester subject established by Belski *et al.* was statistically significant. The Mean value of student responses to the statement "*I am certain that I am able to resolve any problem I will face*" changed from 2.82/5 to 3.82/5 (Belski et al., 2013, p. 350). The response of the NZDE students to the same statement after learning the heuristics is presented in Table 1. The Mean was 3.65/5, pretty close to 3.82/5.

Students that participated in this study assessed the educational materials provided by the TRIZ Repository that they used as helpful. As shown in Table 2, they agreed with the usefulness of each component of materials available for each heuristic and 'liked' the Video and the Solution Template the most. This suggests that the educational materials that are available at the TRIZ Repository website can be recommended to students for self-learning.

The data presented in Table 3 as well as student comments indicate that a short encounter with simple TRIZ heuristics not only helped them to generate more ideas for their projects, but also made a positive influence on the way they analyse and solve problems. Interestingly, the heuristic of *8 Fields of MATCEMIB* assisted some students in revealing to others the ideas that they had in mind, but were unwilling to share openly.

As it has already been mentioned, not all students showed enthusiasm to upgrade their thinking skills and to participate in activities focused on learning the TRIZ heuristics. Such behaviour is not unique to the introduction of heuristics. Students are often reluctant to engage in any task that is not formally assessed and could not improve their course performance. It is also possible that some final year students hesitated to use the heuristics. Many of them might have had ideas on conducting their project work already and were unwilling to make changes to the ideas that they have developed prior to learning the heuristics.

It seems that in order to actively engage students in learning thinking heuristics and to help them in utilising the outcomes of problem analysis and idea generation achieved with these heuristics it is necessary to make heuristic application a compulsory part of project proposals, and to formally assess the outcomes of the application of heuristics. It would also make good sense to introduce TRIZ assignments in the first-year engineering subjects. Embedding thinking heuristics into early engineering subjects is likely to help students later on, for example in their final year capstone project. If problem solving heuristics are introduced to students from year one, they will have ample time to familiarise with the thinking heuristics before their project work will commence and may be able to accomplish more during their project work.

Conclusion

It has been found that a short introduction of TRIZ heuristics to students enrolled in NZDE resulted both in tangible and intangible outcomes. Many students reported that as a result of learning TRIZ heuristics they came up with new ideas for their projects. Also, students thought that their problem-solving approach has changed as a result of learning TRIZ heuristics and that they will use these heuristics in the future.

Introduction of TRIZ heuristics did not take much time and effort. Appropriate teaching and self-learning materials were simply downloaded from the TRIZ Repository. Therefore, engineering educators may need to consider utilising the resources offered by the TRIZ Repository in their own courses.

Although the majority of the students that participated in this study were excited to learn thinking heuristics, some students were reluctant to devote their time to the heuristics. In order to ensure that all students consider enhancement of their cognitive skills seriously and devoting appropriate time to studying thinking heuristics it is recommended that the heuristics are introduced to students early in their engineering study. They need to be given adequate time to familiarise with the thinking heuristics in order to effectively use these heurists in their project work.

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Implementing MUSIC Components to Enrich Engineering Capstone Projects: The Students' Perspective and the Instructors' Standpoint

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Effective teaching involves engaging students in ways that are appropriate to the development of deep approaches to study. Deep approaches are encouraged by creating opportunities to a responsible choice of study, by demonstrating meaning and relevance of content to students, by implementing teaching and assessment methods capable of motivating active and long-term engagement, clearly stated expectations, interest in the subject, and educational settings. Capstone/engineering projects, which explore problem-based learning (PBL) approaches, provide an opportunity for students to practice applying their knowledge and workplace skills while they engage in a collaborative environment. PBL could be effective if teaching and learning methods were meticulously set in terms of course preparation, scenario design, implementation, and assessment.

PURPOSE In this article, we investigate how instructional elements of problem-based learning can affect students' engagement in capstone engineering courses and help them to feel prepared to work effectively in their profession.

APPROACH The effect of the five components of the MUSIC Model: eMpowerment, Usefulness, Success, Interest, and Caring, on students' motivation and their ability in problem solving, critical thinking, coordinating with others, and cognitive flexibility, was measured in relation to students, their teammates and instructors. We used a two-phase mixed method approach including both quantitative and qualitative assessments. In the quantitative phase, a group of students in Engineering/Capstone Project from civil engineering department completed a questionnaire with a set of questions related to the MUSIC components and their responses were analysed in a qualitative phase.

RESULTS Results of two-phase mixed methods approach revealed that if motivating opportunities are used properly, they can foster students' positive perceptions of the MUSIC components, and avoid frustration and the lack of motivation. These motivating opportunities are important because they can help instructors to plan and implement PBL instructions more effectively and improve student's engagement.

CONCLUSIONS The qualitative data analysis indicated that three categories of PBL were relevant to students' motivation: project design, group experience, and project advisor. The findings in this article can improve students' success beliefs by making course expectations clear, assessing students at an appropriate level, and providing continuous feedback.

KEYWORDS MUSIC components, Capstone Projects, Problem-based Learning.

Background

In a majority of engineering subjects, educators have shifted away from factual (didactic) teaching towards contextual teaching in the form of problem-based learning (PBL) (Epstein, 2004). The aim of PBL is to acquire the ability to 'learn to learn' and construct new knowledge, rather than what is actually learned or taught (Healey, 2005). Various studies highlighted that PBL also promotes deep learning through greater understanding of concepts and development of skills, while fostering student participation and motivation, which can cultivate lifelong learning (Epstein, 2004; Pawson et al., 2006; Ribeiro, 2011). PBL can be interpreted as 'problem first learning' (Spencer & Jordan, 1999) in which instructors set a problem which defines what is to be learned. Curriculum, course or assignment contents are organised around problem scenarios, rather than subjects or topics (King, 2001). It demands from the learner the acquisitions of critical knowledge, problem-solving efficiency, self-directed learning strategies and team participation skills.

The PBL stimulates learning through the replication of challenges that students can encounter in life/career and requires them to determine appropriate learning resources. This can be achieved through curricula that promote students' general and scientific knowledge, integration of theory to practice, development of interpersonal, written and oral communication skills, students' critical and conceptual reasoning, the capacity to reflect on their own practices and learn from practical situations (Tynjälä, 1999), without extending the period of formal training (Ribeiro, 2011). If PBL is implemented poorly, there is a chance that the students may not identify the relevance of the learning materials to their future engineering career. This lack of understanding can be demotivating for students' learning (Kember et al., 2008) and teachers may be seen as the imparter of knowledge, as students merely reproduce and regurgitate said knowledge. This is known to lead to lower levels of effective learning. As a result, appropriate implementation is a key part of a successful PBL approach.

PBL involves not only educational and institutional changes, but it also demands individual changes from students and instructors. The implementation of PBL requires participation, planning, and cooperation of students and teachers. Implementation of this process is challenging as it requires students' and teachers' involvement and it is time consuming. The process of PBL brings a more complex and uncertain situation for a teacher than conventional lectures (Ribeiro, 2011). In PBL settings, teachers need to act as a co-learner, guide and facilitator. These multiple responsibilities demand preparation, planning, time and a good knowledge of the subject.

An important risk in PBL is related to the design of problems for students to solve. The problem should be real, complex, and multi-dimensional to allow students to work as a team, and well-designed in order to be solved in a specified time frame. However, the definition of such problems also makes students' learning more demanding, as they need to simultaneously allocate the time to learning other subjects. The problem should have clear outcomes and need to be well translated to the group of students. The teacher is responsible for forming groups to work on a problem and should assign each student specific roles in order to avoid barriers to participation. The teacher should also probe the students with questions which promote critical thinking. The effectiveness of PBL, however, could be compromised by poor group dynamics amongst students, in which case timely intervention from teachers' is a requirement to mitigate the issues.

As an engineer, students will face different problems in their professional life and they need to rely on their engineering judgement to solve and overcome challenges. As workplace, professionals, they are required to demonstrate their ability in problem solving, critical thinking, coordination with others, and cognitive flexibility. Capstone projects provide an opportunity for students to practice and improve their knowledge and workplace skills while they engage in a collaborative environment.

Jones et al. (2013) investigated how instructional elements of PBL can affect student's engagement in capstone engineering courses. They measured the effect of five components of the MUSIC Model: eMpowerment, Usefulness, Success, Interest, and Caring, on students' motivation. Instructor interaction is a motivation element and some students mentioned that they benefitted from their instructor's feedback since it reinforced the sense that they are supported, while other groups found confronting to obtain feedback from their advisors. This lack of feedback hindered students' success. They claimed that students can still be motivated even if all the MUSIC model components not reach high levels. This can be due to the fact that instruments used in this research were developed and validated by different researchers for various purposes.

MUSIC Components in Capstone Project

In this section, we discuss about the relationship between authors' teaching/supervisory method, and students' motivation and approaches to study. To support this, we completed a questionnaire from students in Engineering/Capstone Project at the University of Sydney and identified the key elements of our teaching methods based on the four lenses of Brookfield (1995). This unit of study (UoS) provides a great opportunity for students to conduct original investigation and research work. Students generally work in groups, although the planning and writing of the thesis is done individually. Working arrangements are informal, as are the relationships between the students and their supervisor. This unit can help students to improve critical thinking, problem solving skills, and decision making. Students learn to improve their ability to explore and formulate appropriate methods for investigating research questions. At the end of the unit, the students are expected to have in-depth knowledge of the area which most likely helps them to find their future job.

Based on Ramsden (2003), effective teaching involves engaging students in ways that are appropriate to the development of deep approaches, such as exercising responsible choice of study, demonstrating meaning and relevance of the content to students, teaching and assessment methods to motivate active and long-term engagement, clearly stated expectations, interest in the subject, and educational settings. In this light and similar to Jones et al. (2013), we tried to measure the effect of these five components (MUSIC Model): eMpowerment, Usefulness, Success, Interest, and Caring, on students' motivation. We measured these components in relation to students, their teammates and instructor. We used a two-phase mixed methods approach, comprising both quantitative and qualitative approaches. In the quantitative phase, the students completed a questionnaire with a set of questions related to the MUSIC components and their responses were analysed in the qualitative phase.

Currently, we are supervising 3 groups of undergraduates and two master thesis students. For undergraduate and post-graduate students, group sizes are comprised of three and one student per group, respectively. To learn about our students' motivation and approaches to learning and to reflect on our teaching philosophy, we selected students from each group, all of them in the final year of their civil engineering degree. Students are from different countries and levels (undergraduate/post graduate). Undergraduate students are from China (Students A–C), Malaysia (Student D), and Australia (E–G) while the postgraduate student is from Guatemala (Student H & I). The questionnaire was designed to determine students' motivational parameters and their approaches to learning during the final year project. Table 1 summarises items in the questionnaire. The first two questions of the motivational part focused on students' major (civil engineering, double degree, etc.) while the remaining questions attempted to discover students' motivation and approaches to learning in the unit of study. Students were notified that all aspects of the study, including results, will be strictly confidential and that they will not be identified in anything they write. Participation was also voluntary and participants were instructed to type their answers to each question prior to our weekly meetings and then to print it and bring it along to the class where a table at the back of class was assigned for collection of the questionnaire and Consent Forms.

Table 1: Targeted items in the questionnaire for the current study.

Motivation	Approaches to learning
How did you come to choose this course?	How did you determine the topic you selected?
Can you mention a unit of study that you really enjoyed in the course? Why did you enjoy it?	Can you please describe what you are doing in order to learn during this unit?
Are you interested in the context of this subject? What makes it interesting/not interesting for you?	What do you think influences you to learn like that in this subject?
Do you feel in control of your learning in this context? If not, what is your suggestion?	What would convince you to take a different approach?
Do you believe you can be successful in this subject?	What is the workload like in this subject?
Do you think the content/topics are (or will be) valuable to you?	How do you approach the assessments?
How do you think this subject can help you in your short-term/long-term goals?	Describe your group's dynamics?
	What would you change about the role of your advisor?

Discussion

By analysing the questionnaire responses, it was revealed that if motivating opportunities are used properly, they can foster students' positive perceptions of the MUSIC components; otherwise, they lead to students' frustration and a lack of motivation. For instance, we believe one element of collaborative learning that influenced participants' motivation is the students' freedom in the selection of their project. Time is another important parameter in designing successful courses. Some motivating opportunities are established prior to the start of the course, such as the student's freedom to choose their topic, group, or advisor. Therefore, it is important to investigate the parameters that move the course dynamic towards a professional engineering environment and to consider how these parameters vary with time. Three students noted that they had the opportunity to select a project based on their individual interest, whereas Student H chose the topic after consultation with his supervisor. Student D mentioned that: "this topic is selected by my teammate and we are both interested in the topic since it involves experiments". It appears that most of students selected topics that are tied to their career plan: "… to achieve good knowledge in that particular area", "… in the context of structural (engineering)", or "… to gain enough knowledge and (to) apply it to everyday situations". This is closely related to their motivation (i.e. personal interest or future job prospects, studying something more practical) for selecting their course in the first place, too. Students who do not believe the project matches the real-world practice or it does not meet their career goal expectations experienced motivation problems. It is critical to design the project in a way to interest students and to be useful. Since the sample size in this qualitative questionnaire was relatively small and all participants had the freedom to choose their project, the authors were not able to measure students' motivation level when the project topic was enforced without particular care for their individual or career interests.

Students' self-efficacy was measured by asking the students to reflect on their ability to organise and implement the actions needed to perform effectively during the project. This unit of study consists of two year-long engineering/capstone projects. To the authors' interest, all students strongly believed that they will be successful in their project even in the middle of the first semester. This may be due to the: students' interest, clearly stated expectations (guided journal which was provided during our first meeting), interactions with peers, or feedback received from their supervisors. This can show the link between motivation, interest and assessment. Good teaching implies engaging students in ways that are appropriate to the development of deep approaches. Research (Ramsden, 2003; Bandura, 1977) indicates that students with high self-efficacy adopt a deep rather than a surface approach that positively influences students' motivation and achievements. Having said that, the authors are planning the students to complete another questionnaire at the final stages of their project during second semester to understand how these motivational opportunities fluctuate throughout the unit. This is important because it can help the instructor to plan and implement educational methods more effectively and to improve students' engagement and success beliefs by making course expectations clear, assess the students at an appropriate level, and provide continuous feedback.

Using a mixed-methods research approach, Dunlap (2005) studied how self-efficacy during a problem-based learning (PBL) experience can help the students feel prepared and work effectively in their profession. The author examined 31 undergraduate university software engineering students during a 16-week capstone course prior to graduation. Results of this research showed that acquisition of skills is not enough to be competent in the subject and requires another element, i.e. students' self-efficiency, which is interpreted as students' individual level of confidence to perform effectively. This finding is particularly interesting to our project because it can help us to suggest specific instructional strategies to improve students' performance. Dunlap (2005) used guided journals to process data and to scale self-efficacy based on collaboration and reflection. Results showed that journal writing not only can foster understanding and enhance student's critical thinking and achievement, but also is an effective way to capture students' reflective practice, conceptual change, thinking, and learning. Changes in students' confidence was measured at three intervals: before, during, and after PBL experience. Dunlap's (2005) results showed that all students expressed a lack of self-efficacy prior to their PBL experience which was improved during the course, and replaced by confidence at the end when students started referring to themselves as software developers rather than students. The author also pointed out the importance of early and frequent opportunities for students to engage in PBL and work on professional practice. In this paper, Dunlap (200) claimed that student growth in self-efficacy was a result of participating in PBL since students were exposed to the PBL environment for the first time.

Based on our previous experience, students who collaboratively get involved in a research-intensive environment improve their critical thinking and hands-on skills. Working as a group provides various opportunities to motivate students. Some participants felt it empowered them regarding group's dynamics and work allocation: "my groupmate and I work together a lot and we learnt a lot through discussing and searching for information …"; or other highlighted that their group interaction was motivated through a friendly environment: "… everyone is very friendly and helpful, I like to work with them".

> Student E: We have been friends for years and have been in groups for many previous subjects so our group dynamic was fine.

As teachers, we try to develop a mentoring relationship with our students and develop their scholarship in the field. Students learn best through reflection, as it enables them to become reflective and collaborative thinkers who are also effective communicators. Through reflection, students are able to understand themselves more and then understand their learning better. As much, we arranged weekly meetings for students to reflect on their progress. Students present their approaches and discuss the outcomes in front of other groups. Meetings take almost one hour and thirty minutes. Each group is assigned about 20 minutes to discuss their findings/issues. Some of the students highlighted that weekly meetings with their supervisor and their peers help them to improve their learning process. Students B, D, and E noted that perhaps more one-to-one discussion sessions with their supervisor would help them to make sure they are on the right track;

> Student E: Advisors did a good job. Only recommendation would have been to have more individual time with each group to focus on specific issues at hand.

Student H raised a concern about how the feedback from supervisor is provided: “I would like to have a better approach on how the feedback is given, and how they (supervisors) use their expertise to give us better ideas”. This is one important parameter to consider; consequently, we need to revise structure of our weekly meetings in order to shift towards a teaching style students are more accustomed to in an effort to help with their approaches to learning.

Conclusion

Capstone projects encourage the students to think and interact with the environment which is said to have a positive effect on their learning. It also motivates the students to research and learn contents as they encounter real life problems. Problem-based learning approach in capstone projects triggers students’ basic knowledge, skills, group interaction and self-learning abilities. In this project, we discussed the benefits and risks in the implementation of PBL for engineering students in their final year projects. This process involves individual’s (i.e. student and instructors) involvement in the evolution of teaching and learning process. It was shown that PBL would be effective if teaching and learning methods are meticulously set in terms of course preparation, scenario design, implementation, and assessment. Implementing of PBL in a course can result in higher levels of students’ and teachers’ satisfaction, and foster the teachers’ development of their teaching knowledge foundations to promote students’ knowledge, critical thinking, and interest. Based on this, MUSIC motivating components were used to characterise the effectiveness of PBL in active learning during a capstone project. These motivating opportunities are important because they can help instructors to plan and implement PBL instructions more effectively and improve student’s engagement. The findings in this article can help to improve students’ success beliefs by making course expectations clear, assess students at an appropriate level, and providing continuous feedback.

Finally, authors believe that a larger set of students from different engineering disciplines should be surveyed in future research in order to achieve more statistically significant evidences.

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International Student Online TRIZ (Teoriya Resheniya Izobretatelskikh Zadach) conferences: organizational experience and perspectives

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S2: Educating the Edisons of the 21st Century

CONTEXT The motivation of many students depends very much on the ability to apply their knowledge and skills in practice. An important motivation is the assessment of their achievements by peers, both at home and abroad. The standard format for communication between students and specialists are conferences; however, the participation in international conferences is associated with significant financial costs. There are a lot of extramural conferences, when participants get acquainted with the colleagues' reports only in printed form, but the effectiveness of such conferences isn’t high enough. The intramural conferences allow to quickly communicate in a question-answer format, in addition, the emotional component is high.

PURPOSE The purpose of international student online conferences is to develop the students' ability to communicate openly with their peers, not only in native language, but in English, and also to develop the ability to effectively: a) present the scientific results; b) present their ideas, taking into account the infographic requirements, as well as in the public speeches form; c) visualization of their portfolio; d) practical application of knowledge obtained in the study of TRIZ disciplines.

APPROACH "TRIZ technology" conference was organized at the Komsomolsk-on-Amur State Technical University (KnASTU). Students from universities of different countries (Russia, South Korea, China, Japan and so on) participate in it, and these universities must preliminary proceed with an application and conduct testing of communication equipment. The conference was traditionally held in two stages: selection (within each country, in the native language) and international (in English), during which the three best reports on several nominations were selected.

RESULTS The conference is held annually, starting in 2011, and it will be held for the seventh time this year. The number of reports each year is approximately the same – no more than seven reports from each country. The quality of reports, as well as the activity of students, according to experts, are increasing year by year.

CONCLUSIONS Learning motivation of TRIZ disciplines is increasing among students – there is an exchange of experience in the use of TRIZ, not only among students but also among educators. The contingent of the conference participants is expanding, in the direction of reducing and ascending the age and experience of participants, – school children, masters and post-graduate students have been involved.

KEYWORDS International Student Conferences, online, TRIZ

Introduction

One of the prior tasks of any educational system is training high-skilled professionals for domestic economy, and also the integration of higher educational institutions into the international system of education. Clearly, such an integration is not possible without successful implementation of long range programs of international cooperation. Moreover, these programs can be implemented in different directions - scientific research, innovations and technologies, education, culture, etc.

As a rule, benefits of universities, which actively present themselves on the global stage, are obvious (Sytnikova, 2016):

- profile raising and strengthening;
- achievement of global level competitive ability of results of activity (educational, scientific and research, applied, technical);
- increasing number of enrollment contracts;
- additional university financing, etc.

However, international cooperation of students under university programs is profitable not only for reports quality and financial performance of an institution. It significantly increases the motivation of students for their further professional activity and also is able to increase efficiency of students' work on solving serious tasks doing a course, graduate and post graduate qualification works and making projects.

As for authors' experience, the positive result is caused by several reasons:

- students share experiences and gladly extend their professional perspective (it's one thing to learn facts from literature, but it's totally another to learn it from foreign agemates);
- unavoidable language barrier (the same event can be participated by students from different countries) is a tool for partial elimination of psychological inertness and for deactivation of social stereotypes - students appear to be too busy with communicational issues;
- communication decreases the level of stereotypes of particular persons by means of national stereotypes crossing;
- students get the opportunity to evaluate their level in comparison with international colleagues - draw a conclusion, make an "error correction", choose new vectors of development and personal growth.

What about forms of international cooperation, it can be: international inter-university exchange programs; cooperative research centers; technology parks and incubators; international conferences, symposiums and forums; workshops and colloquiums; internships and off-site educational sessions, etc.

In the paper there is an analysis of the experience of holding international conferences oriented to solving professional tasks by using TRIZ tools.

International problem-project training

Project-oriented learning activity assumes design and creation of an ideal or material innovative product. It is a creative training activity of solving practical task, goals and content of which are defined by students and are achieved by them during the process of theoretical studies and practical implementation under the consultation of an educator or an expert.

Demonstration of multimedia materials grouped by appropriate subjects can be considered as the mechanism of guiding students' creative activity in a required educational process.

Knowledge gained in the process of project-oriented training is sustained, because different educational subjects interwork each other instead of being learnt separately. Such training model includes working with problems of the real world and practical activities. The project task is to master some particular subject instead of looking for correct answers for educator's questions. Over the project-oriented training students work together with each other during a period of time to prepare a project and present their work for experts after project finishing (Vladimirova, 2011).

As for problem-oriented training, it is a technology of inquiry-based learning. The base of problem-oriented training is the principle when students formulate a practical or theoretical problem. Further revision of the formulation by an educator is possible. Students solve the problem individually or in micro-groups. In this case lessons are formed on the base of inquiry-based learning algorithms. Basing on the problem-oriented training, it is possible to learn a section or the whole educational course (for example, elective or selective course) (Voevodskaya, 2011).

The problem-project approach to the TRIZ tools mastering

Considering the main stages of approaches described above and restrictions imposed by incidental cross-national students' meetings and time for preparing graduate qualification work and (or) master's thesis, we suggest the following stages, which require obligative on-site (live-distant) interaction of all parties of the process - students and educators (including TRIZ experts):

- introductory lecture course on TRIZ basics (1 stage); main goal - formulation of a problem;
- international workshop (2 stage); main goals:
  - specification of task list;
  - generation of fair number of conceptual ideas;
  - elaboration and efficiency comparison of draft projects;
- international forum (3 stage); main goals:
  - technological exchange;
  - acquaintance with new methods and methodologies of solving tasks;
  - development of personal methods;
- international conference (4 stage); main goals:
  - presentation of existing projects;
  - experience exchange;
  - development of new joint directions of the further cooperation.

Figure 1 shows the schedule of events. In brackets, there is an indexing of master students' terms. Arrows show ranges of running events during a term, circles indicate suggested dates of running events.

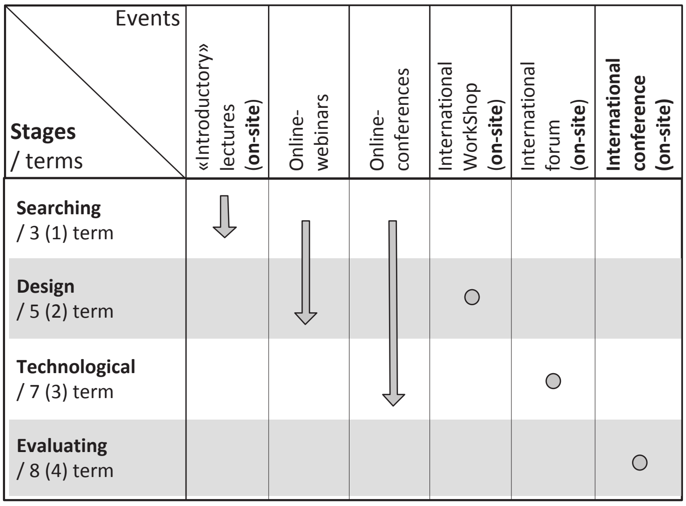

Figure 1: Schedule of events to a term base (Redkolis, Berdonosov, 2017)

At the *stage 1,* students attend a number of introductory lectures. They focus on TRIZ methodology, get acquainted with base tools, reveal a relevant problem and formulate a draft task, the solution of which leads to the problem elimination. During the stage educators' goal is to explain each student theoretical mechanisms, which shall be used in the further work.

At the *stage 2* the following activities are performed: collective interaction with each other with the use of theoretical mechanisms, elaboration of initially formulated tasks, preparation of detailed but still draft project; in the case of positive dynamics rough detailed engineering is possible.

The next *stage 3* is performed in theoretical form. During a forum students learn better from experts than work on their own. They discuss and analyze realization details of ideas and generated solutions. They also take into account experts' proposals and suggestion, but don't work on projects.

At the time of the forum all students proceed to in-depth detailed engineering. They face a rising need of particular tools analysis, exchange of experience and some details appeared during the realization. Notably, the task of students is not only to receive information about new technologies and design procedure, but also to discuss individual questions about their projects with experts, not among themselves (as in the previous stage).

Final *stage 4* is hinged on presentations of developed projects, its' discussions, critical analysis and determination of future research spheres.

As for *online events*, frequency and duration are not beforehand scheduled and are set basing on "student-educator" feedback. For example, if it is necessary to elaborate an issue and discuss a theme (there are comprehension questions), on-line webinar shall be organized. If there are many ideas and it is hard to choose one of them or there are several potential solutions of how achieve some goal and it is necessary to use only one (there are principal issues of project realization), online conference of ideas shall be organized.

By now, the most developed form is international online students' conferences, which will be further discussed.

Technique of organizing the conference

Huge organizational work precedes the conference and comprises the following spheres: software, hardware, informational support, language support, financial support.

From the very beginning, it was suggested that there should be a center (central university), which shall coordinate the whole project. Komsomolsk-on-Amur State Technical University

(KnASTU) became such a center. Besides, initially it was suggested that two or three counties would be involved with the project and then the number of countries would be increased up to 5. Participating countries were selected in accordance with two criteria: minimal lag time as for the center (one-two hours) and the existence of developed educational infrastructure in terms of TRIZ.   As KnASTU is located in Khabarovsk region (Russia) and Khabarovsk region is located in UTC+10 timezone, so the following countries meet the first criterion: China (UTC + 8), Philippines (UTC + 8), Malaysia (UTC + 8), Indonesia (UTC + 8), Taiwan (UTC + 8), South Korea (UTC + 9), Japan (UTC + 9), Australia (Melbourne, UTC + 10). Website MATRIZ.org (Yakovenko, 2005) allows considering educational infrastructure in terms of TRIZ in countries selected by the time criterion. There are the following countries: Australia - Royal Melbourne Institute of Technology (Professor Iouri Belski), China - Beijing University of Technology (Professor Guo-hua GAO), Japan - Osaka Gakuin University (Professor Toru Nagakawa), South Korea - Korea Polytechnic University (Professor Yong Won Song), Taiwan - National Tsing Hua University (Professor Sheu). These countries were chosen to participate in the project. For testing period Russia and South Korea were chosen.

Software selection was performed in accordance with the following criteria:

- minimal audio and video data deference, deference of more than 3 seconds is unacceptable;
- connection of up to 10 conference participants (5 countries, 2 university per a country);
- simultaneous transmission of report presentation, voice and video of a reporter, video from conference halls of all participating countries;
- transmission of administrative functions to any participating university;
- ability to record reports and discussions during the conference;
- minimal cost (ideally, free) for client application.

In accordance with considered criteria Russian software TrueConf (Odintsov, 2010) was chosen.

Recommended hardware is shown in figure 2.

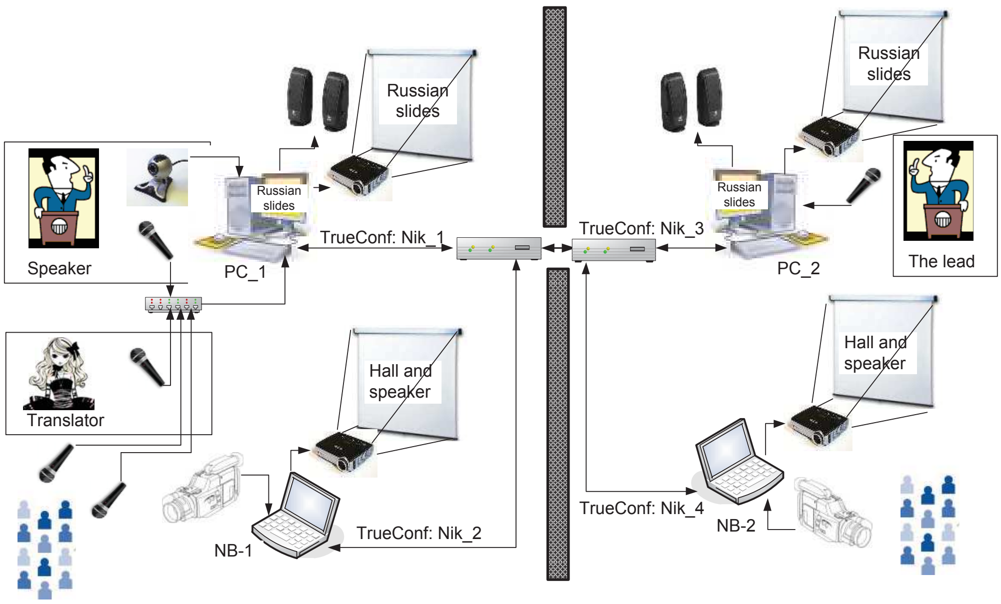

Figure 2: Chart of hardware connection during the conference

Language support. The working language of the conference is English. As a rule, students from different countries are able to read reports in English, interpreters help to translate questions and answers during the discussion.

Financial support. There were financial costs only in 2011, when the central university (KnASTU) bought a license for a TrueConf video conferencing server for 10 users, client application was free. Now, both server and client parts of TrueConf program are free (up to 10 users).

Experience has shown that the most effective solution is to hold two stages of the conference: during the first (national) stage reports are selected to be presented during the second stage. Second stage is international.

Let's proceed to the experience of holding such conferences in the period of 6 years.

Experience of the conferences

Conferences have been held since 2011 up to the present time. Initially, as it was planned, the conference was held between two universities: KnASTU (Russia) and KPU (South Korea), later - between four universities: KnASTU (Russia), Beijing University of Technology, Harbin university of science and technology and Heihe University (China). Then, for two years we returned to the two universities format to solve technical and technological problems and since 2015 we have returned to the four universities format (see table 1).

Table 1: Participating countries per years

Countries and Universities	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Russia. Komsomolsk-on-Amur State Technical University (Komsomolsk-on-Amur)	+	+	+	+	+	+	+
South Korea							
Korea Polytechnic University (Siheung)	+		+	+	+	+	+
Korea Institute of Science and Technology					+		
INHA University in Incheon;					+	+	
Kumoh National Institute of Technology						+	
China							
Beijing University of Technology (Beijing),		+					
Harbin university of science and technology (Harbin),		+					
Heihe University (Heihe)		+					
Taiwan							?

Figure 3: Photographs of conference process: a) screens of participating universities, right to left from top to bottom - KnASTU (Russia), Harbin University of Science and Technology (China), Beijing University of Technology (China), Heihe University (China); b) conference hall - presentation of the report from Beijing University of Technology (left), display with screens of participating universities.

Report categories have varied during the all time, but there always were four of them. Due to extending the range of reporters (see table 4) report categories for pupils (TRIZ for solving everyday problems, TRIZ for solving problems of household appliances) and post graduate students (Usage of the TRIZ evolutionary approach) were added to traditional categories (TRIZ for solving practical production tasks, ARIZ for solving tasks).

Table 2: Evolution of report categories per years

Categories	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
TRIZ for solving practical production tasks	+	+	+	+	+	+
ARIZ for solving tasks	+	+	+	+		+
Application of inventive principles	+	+	+			
TRIZ for non-technical spheres	+	+	+			
Usage of the TRIZ evolutionary approach				+	+	+
TRIZ for solving problems of household appliances					+	+
TRIZ for solving everyday problems					+	
Investment to future				+		

The conference is traditionally held during a day and the number of reports is limited by 14-16 per year. It is interesting how the number of reporters depends on nationality: in Russia there are mostly not more than 2 coreporters (with pupils' participation, this number increases); in South Korea the number of coreporters is traditionally bigger (up to 8).

Table 3: Specification of reports and reporters per years

Countries and Universities	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Aver age**
Total reports	18	14	14	15	16	13	15
Russia	12	7	6	6	8	6	7.5
South Korea	6	-	8	9	8	7	7.6
China	-	7	-	-	-	-	7
Total number of coreporters	20	28	15	50	43	34	32
Russia min/max	1/2	1/2	1/1	1/4	1/7	1/2	1/3
total	13	9	6	10	23	8	11.5
average	1.08	1.29	1	1.7	2.88	1.14	

South Korea min/max	1/2	-	1/3	2/7	2/3	2/8	1.6/4.6
total	7	-	9	40	20	26	20.4
average	1.17	-	1.12	4.4	2.5	3.71	
China min/max	-	1/4	-	-	-	-	1/4
total	-	19	-	-	-	-	19
average	-	2.7	-	-	-	-	-

Table 4: Evolution of reporters range

Countries and Universities	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Aver age**
Reporters range							
Russia							
Pupils	-	-	-	4	9	1	4.7
Bachelor students	6	2	4	4	7	5	4.7
Master students	7	7	2	-	5	2	4.6
Post graduate students	-	-	-	2	2	-	2

Projects presented at the conference

Part of the conference reports are the results of finished scientific projects, and some of the reports are the beginning of a project.

For example, the report “ARIZ application to improve efficiency of thermal power plants” is the result of the project of saving cooling tower injector components from icicles which are formed on walls of cooling towers.

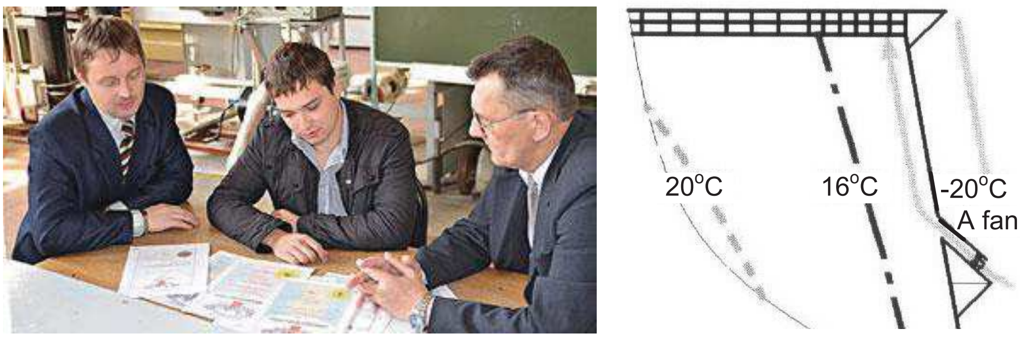

Figure 4: Discussion of application for a patent, part of the figure from the patent showing the main idea.

Another report “Solar collectors for low temperature areas” (2014) was the only beginning of a project and it is planned to start operation of such solar collectors (temperature range up to -50°C) in 2018 and enter a target market in 2019 (Boldyrev, 2017).

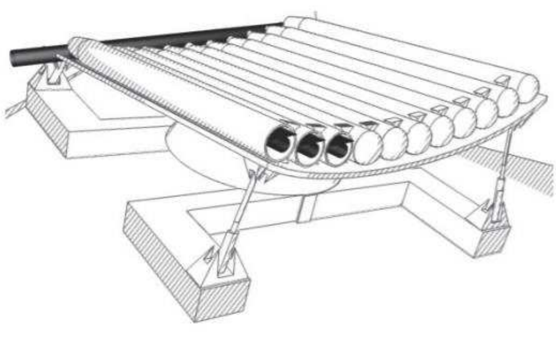

Figure 5: Solar collectors for low temperature areas (Boldyrev, 2017)

Another set of reports is dedicated to analysis of a knowledge field development or TRIZ evolution: “Research of the object-oriented programming mechanisms evolution”, “TRIZ-evolutionary approach as a new educational methodology”, “Research of the object-oriented programming languages evolution”, “TRIZ-evolution of Functional Programming Paradigm”, “Application of TRIZ evolution to analysis of system “Iron”, “Application of TRIZ tools to research social potential of childhood”, “Highlighter life extension”.

To raise public awareness about projects and reports, reports have been published in the conference proceedings since 2015.

Besides, some of researches had been continued during internships in South Korea and Japan.

Conclusions

In general, the method of holding international student on-line TRIZ conferences has shown its efficiency. Sustainable interest in the conference participation is noticed among Russian and South Korean students. Besides, we can see extending reporters range as to the way of youthification (pupils), as to the way of “growing-up” (post graduate students). It is reasonable to broaden the audience of reporters in Australia, China and Japan. In addition, the conference have contributed to deeper learning of TRIZ in universities, which participated in the conference.

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STEM Intervention Strategies: Sowing the Seeds for More Women in STEM

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SESSION

C4: The role and impact of engineers and the engineering profession in the wider community

CONTEXT

In a new study released by the Office of the Chief Scientist (2016), only 16% of Australians in Science, Technology, Engineering and Mathematics (STEM) professions are women. A better understanding of the motivations of, influences on, and barriers to young girls as they form STEM career aspirations, and the implementation of such knowledge towards targeted strategies, may improve the global gender disparity in STEM disciplines. A healthy and diverse STEM pipeline could lead to new perspectives on innovation, creativity, leadership and success, ultimately impacting the world's performance and productivity.

PURPOSE

The purpose of this research is to identify barriers to girls at secondary school entering STEM careers, to propose recommendations for tackling and removing the perceived barriers and to identify methods to tailor existing outreach activities to better attract more female students.

APPROACH

The opinions of 496 girls aged between 12 and 18 from an independent girls' school were gathered via an online survey. Results were used to inform strategies to improve the gender disparity in STEM disciplines via outreach activities, programs and marketing material.

RESULTS

While gender stereotypes, a lack of female role models and negative imagery associated with STEM are still frequently highlighted in the extensive body of literature as a cause for the underrepresentation of women in STEM fields, less than 10% of students in our context supported these claims. The perceived difficulty of STEM subjects and a lack of information surrounding STEM career pathways were identified as the dominant barriers to the uptake of STEM subjects. Furthermore, parents were clearly identified as the key influencers on children's academic and career trajectories.

CONCLUSIONS

Tailored workshop activities and outreach materials that clearly highlight stimulating and diverse STEM career opportunities that are available through the pursuit of highly achievable STEM subjects, in addition to accompanying workshop materials designed for family members, could be key to improving the global gender disparity in STEM disciplines. Future studies with students from more diverse types and demographics of schools should be performed to ascertain if these results are anomalous or signal a wider change in student perceptions of STEM from the wider literature.

KEYWORDS

Women in STEM, STEM Intervention Strategies

Introduction

In a new study released by the Office of the Chief Scientist (2016), only 16% of Australians in Science, Technology, Engineering and Mathematics (STEM) professions are women. A better understanding of the motivations of, influences on, and barriers to young girls as they form STEM career aspirations, and the implementation of such knowledge towards targeted strategies, may improve the global gender disparity in STEM disciplines. A healthy and diverse STEM pipeline could lead to new perspectives on innovation, creativity, leadership and success, ultimately impacting the world's performance and productivity.

The purpose of this research is to identify barriers to girls studying for and moving into STEM careers, to propose recommendations for tackling and removing the perceived barriers and to identify methods to tailor existing outreach activities to better attract more female students. A literature review was performed to gain insight into the current landscape of work that has been conducted within this area. Major barriers to the uptake of STEM subjects comprised of the following:

Masculine stereotypes and negative imagery: There is a vast amount of literature on the perception that STEM subjects and careers are commonly aligned with masculinity, which is negatively correlated with the self-concept of girls. New research conducted by Accenture (2015), who sought the views of more than 1,500 girls aged between 11 and 18 in conjunction with more than 2,500 young women aged between 19 and 23, affirms that gender stereotypes still strongly persist. Similarly, individuals who pursue studies in STEM are often associated with the 'geek' or 'nerd' identity, negative imagery that is often reinforced by the media and by popular culture.

Perception of difficulty: The Institution of Engineering and Technology (2008) traces the current barriers associated with the uptake of STEM subjects, through a literature review of approximately 300 articles. The presumed greater difficulty of achieving higher grades in STEM subjects than in non-STEM subjects profoundly decreased students' self efficacy and interest levels in the subjects.

Parental and teacher influence: In the same study conducted by Accenture (2015), parents were identified as key influencers on children's academic and career trajectories, however a lack of encouragement and uninformed decision making, can inhibit the likelihood of cultivating an interest in these fields. Positive interpersonal relationships with teachers, in conjunction with high quality teaching, have been associated with superior motivation towards the uptake of STEM subjects (The Institution of Engineering and Technology, 2008).

Unclear career pathway: Through Adecco Group's (2015) analysis of the opinions of more than 1000 students aged between 14 and 16, 70% of girls revealed a desire to pursue studies in STEM, however, lacked an understanding regarding potential careers in the sector.

Socioeconomic status: Parents of higher socioeconomic status are more likely to provide greater learning opportunities and better quality educational interactions at home, than parents of lower socioeconomic status. These provisions are necessary for positive STEM trajectories (Wang and Degol, 2017).

Teaching methods: The teaching of STEM subjects are often perceived as "knowledge transmission of correct answers, without time nor room for creativity", negatively influencing the formation of students' attitudes towards STEM (The Institution of Engineering and Technology, 2008).

Methodology

To support research in this area, the results of a literature review informed the design of a theoretically and empirically sound anonymous, optional, online survey, which consisted of both qualitative and quantitative questions. The participants in the survey comprised of 496 girls aged between 12 and 18 (12 – 12.5%, 13 – 17.2%, 14 – 13.5%, 15 – 24.7%, 16 – 18%, 17 – 10.8%, 18 – 3.3%), primarily speaking English (64.6%) and Chinese (34.8%), studying at an independent girls' school (day and boarding) located in an eastern suburb of Melbourne, Victoria, Australia. As an alumnus of the school, such selection deemed appropriate. The survey was announced via the school assembly and distributed through Science lessons in the form of a flyer, with permission from the Principal and support from the Head of Science. The flyer contained a link to the survey, in addition to an Explanatory Statement. Time was allocated during Science lessons to participate in the survey. Survey data provided insights into current attitudes towards, influences on, barriers to, and understandings about STEM subjects and STEM careers, in addition to an exploration of methods to increase STEM subject uptake. Survey results were applied towards generating targeted strategies to improve the global gender disparity in STEM disciplines.

Results and Discussion

Students first shared their opinions regarding the 'discouraging features of STEM subjects', as indicated in Figure 1. Students were able to select multiple answers.

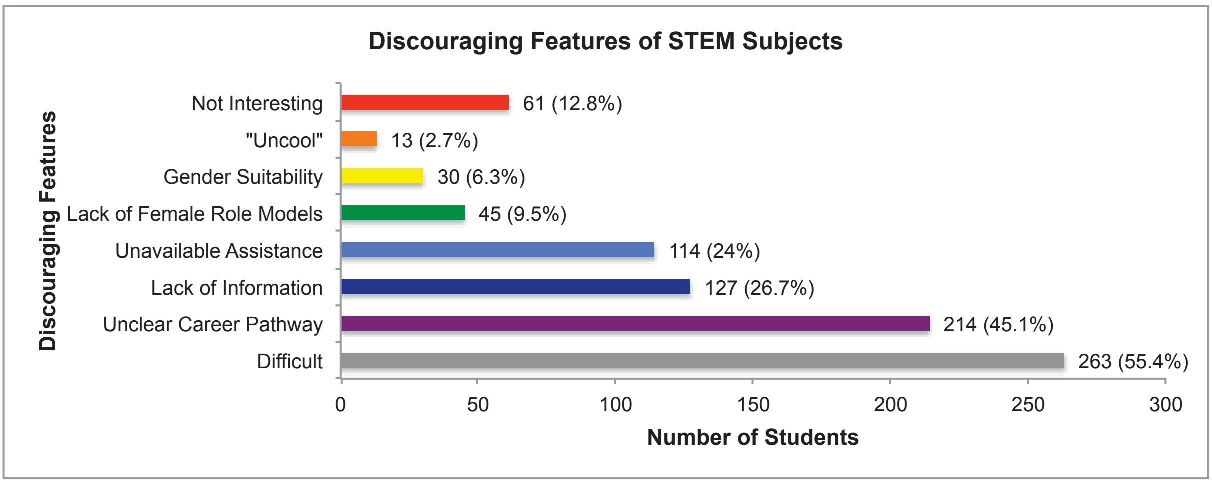

Figure 1: The Discouraging Features of STEM Subjects

Perceived Difficulty of STEM Subjects

The perceived difficulty of STEM subjects was the dominant barrier to students pursuing studies in STEM, with 55.4% of students citing this as a 'discouraging factor'. 76% of students chose subjects based on perceived personal likelihood of achievement, which refers to students' expectations for academic success established from self-efficacy and self-concept (figure not shown). The perceived greater difficulty of achieving high grades in STEM subjects than in non-STEM subjects, in conjunction with the desire to maximize scores to increase tertiary entry opportunities, are key reasons that could contribute to the decline in STEM subject uptake. Interestingly, the notion of 'difficult' is seldom equated with 'challenging', and such concepts are seen as mutually exclusive. This result correlates favorably with the findings of Duffield and Li (2016), in which a distinction between 'challenging' and 'difficult' was formed by students, who wanted to test their abilities on arduous, yet achievable tasks. Furthermore, analysis was performed to determine the precise age in which students lose interest in pursuing STEM subjects based on perceived difficulty. As highlighted in Figure 2, disengagement peaked in 15 to 16 year old students, where 30% of students believed STEM subjects were too difficult to learn. What makes this figure even more alarming is that these negative attitudes have been embedded into students' psyche prior to the embarkment of VCE studies, the final phase of secondary schooling, which may set the trajectory of their careers.

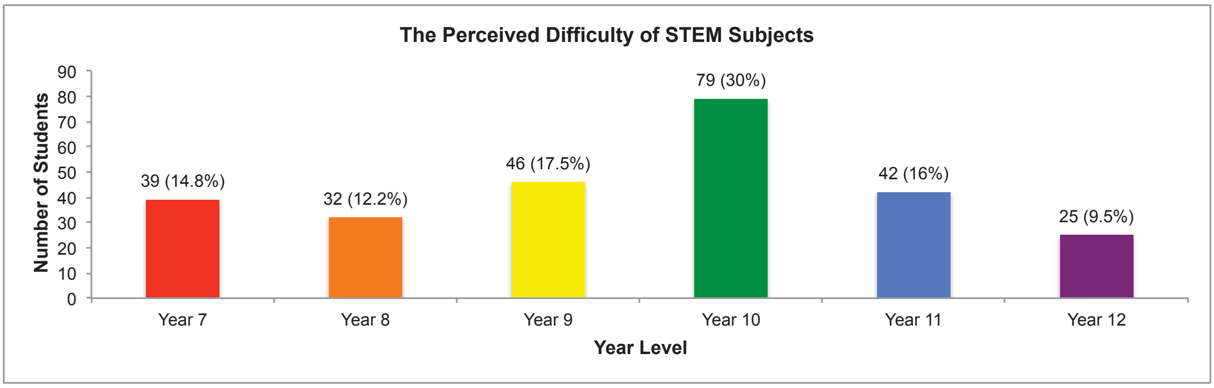

Figure 2: The Perceived Difficulty of STEM Subjects

Lack of Information Around STEM Career Pathways and STEM Subjects

Whilst the perceived difficulty of STEM subjects is the most highly cited discouraging factor, 45.1% and 26.7% of students reveal that a 'lack of information' around STEM career pathways and STEM subjects, respectively, are other major discouraging factors. Perhaps due to insufficient, inaccurate information and misconceptions that occur as a consequence to this, many students fail to see STEM subjects as passports to stimulating, diverse and lucrative careers. Furthermore, as highlighted in Figure 3, despite having access to career advisors, students' understandings about STEM careers are mediocre and fair at best, with only 2% of students possessing excellent insight into what engineering is and what engineers do. However, it is unclear whether career advisors fully understand STEM careers. Additionally, as indicated in Figure 5, only 10.1% of students regard the provision of information, guidance and advice provided by career advisors, as influential.

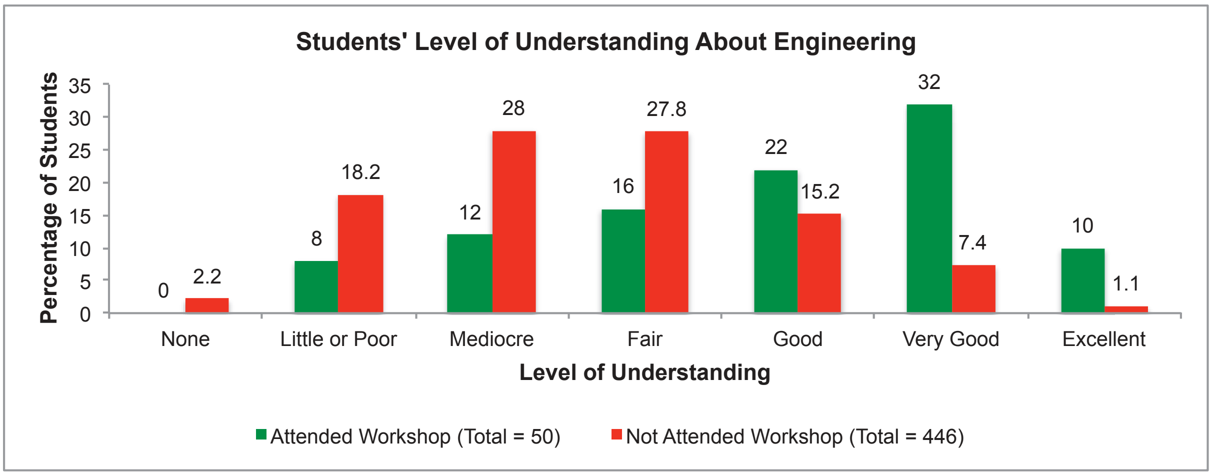

Figure 3: Students' Level of Understanding About Engineering

Quality of Teaching

As a result of the perpetual STEM teacher shortage in schools, STEM is being taught by teachers that have neither a university major nor minor in more than half of schools nationwide (Australian Education Union, 2016). Approximately one quarter of students reported 'unavailable assistance' as a discouraging feature associated with STEM subjects. Such terms were not explicitly defined in the survey. Due to its broad interpretation, a lack of high quality teaching may perhaps be a barrier to the uptake of STEM subjects. Further studies, which remove the ambiguity, will need to be performed to verify such claims.

Gender Stereotypes

While gender stereotypes, a lack of female role models and negative imagery associated with STEM are still frequently highlighted in the extensive body of literature as a cause for the underrepresentation of women in STEM fields, only 6.3%, 9.5% and 2.7% of students surveyed supported such claims, respectively. Gender stereotypic beliefs were explored further through 3 gender-biased questions on a 7-point Likert scale. Students expressed their level of agreement or disagreement to the following questions:

STEM subjects match 'male' careers.

STEM subjects are better suited to boys' brains.

STEM subjects are better suited to boys' personalities and hobbies.

As indicated in Figure 4, students appear to be unaffected by male gender-typed statements. The results suggest that the plethora of gender-targeted STEM strategies to remove gender stereotypes, in addition to the negative portrayal of STEM, may have been successful, at least within this population - girls aged between 12 and 18 studying at a single sex, independent, day and boarding school located in an eastern suburb of Melbourne, Victoria, Australia.

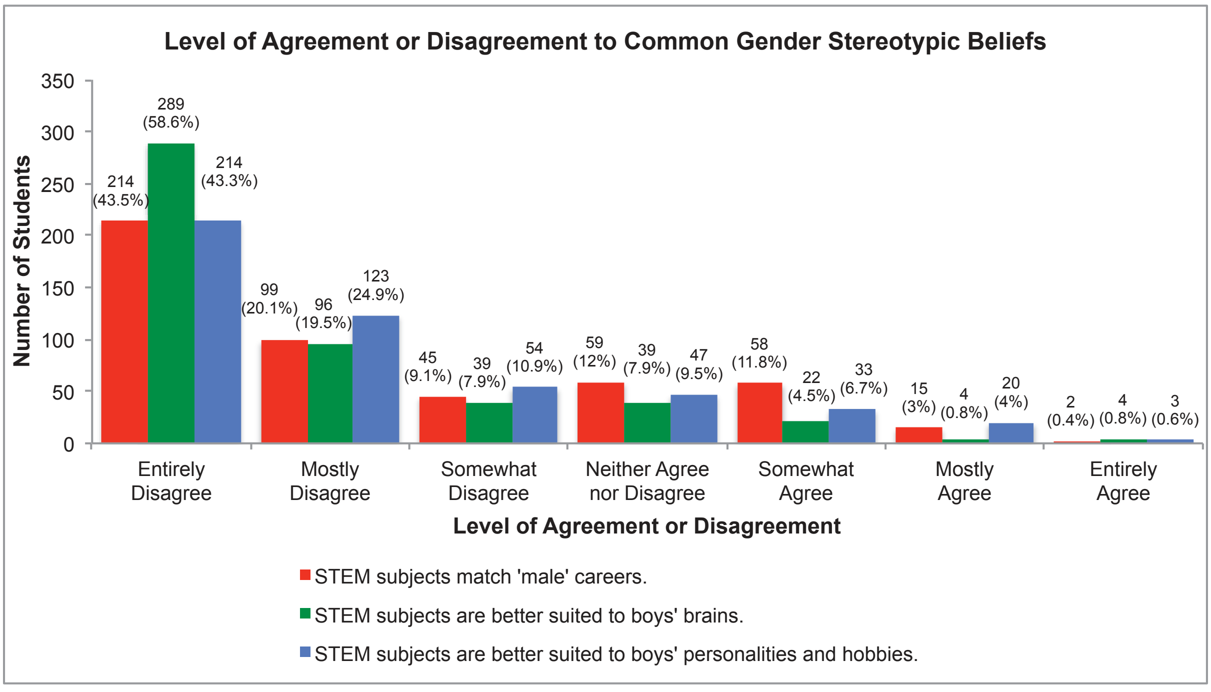

Figure 4: Level of Agreement or Disagreement to Common Gender Stereotypic Beliefs

Influences of Social Contexts

Motivations to pursue certain subjects do not develop in a psychological vacuum, but is evolved under the influences of various ecological contexts, such as family, teachers, friends and society in general (Wang and Degol, 2017). The extent to which these societal factors impact students' uptake of particular subjects was explored through the ranking of students' top 3 selections, as illustrated in Figure 5. Expectedly, 92.9% of students regard parents, family or guardians as influential on subject choice, with 68.4% of students considering such factor as most influential, since the home environments created, the values endorsed and the experiences provided by family members profoundly moulds their academic pursuits. Whilst family holds a dominant role on subject selection, 61.9% of students reveal that educators also play a prominent part in fostering academic motivation, with 36% of students placing teachers as second most influential. This may be attributed to the fact that students spend substantial time in school and are affected by the guidance, encouragement and academic enrichment provided by instructors. The importance of peer relationships during adolescence has been well established throughout the literature where 49.2% of students disclosed that friends exert a major force on their subject choices, with 27.5% of students assigning such factor as third most impactful, rejecting certain subjects to gain social approval by conforming to peer norms. The above results correlate favourably with the findings of Accenture (2015), in which 53%, 52% and 33% of students regarded family, teachers and friends as most influential, respectively.

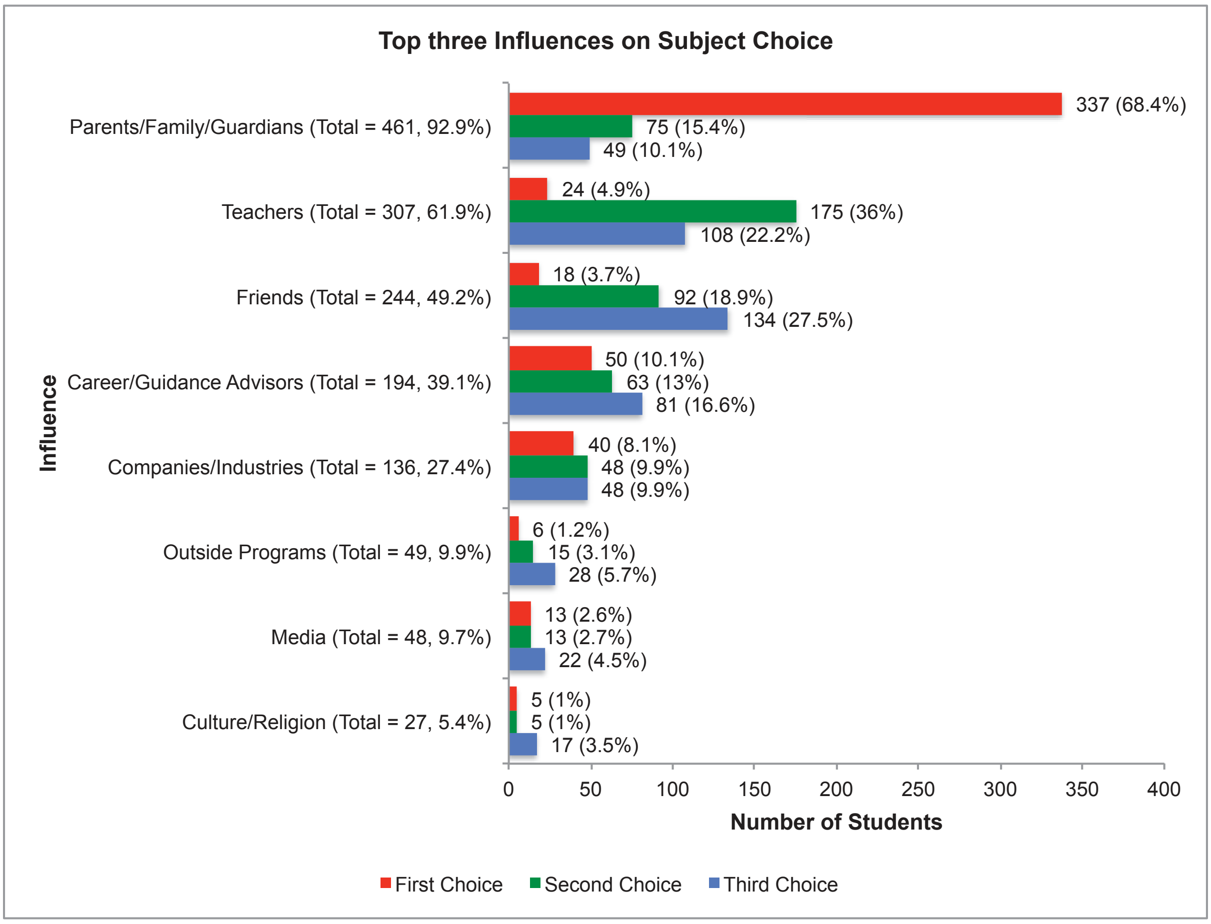

Figure 5: Top three Influences on Subject Choice

Career Aspirations

Students were asked to list the most likely occupations that they would like to choose as a career, with results shown in Figure 6. Whilst 19% of students desire to pursue STEM professions, medicine, nursing and health sciences, were the dominant selections, with 38.1% of students. The perception of the latter is very different from that of STEM, with 54.8% of students associating such profession with great societal value, as compared to only 11.5% for STEM. The objective assessment of the tangible benefits of both careers such as salary and opportunities for career advancement was more preferential towards medicine, nursing and health sciences as opposed to STEM receiving 7.6% and 5.1% responses, respectively. Social and psychological aspects such as family history and personal ability was regarded as least influential on vocational choice but remained superior towards medicine, nursing and health sciences than STEM with 6.4% and 3.8% responses, correspondingly.

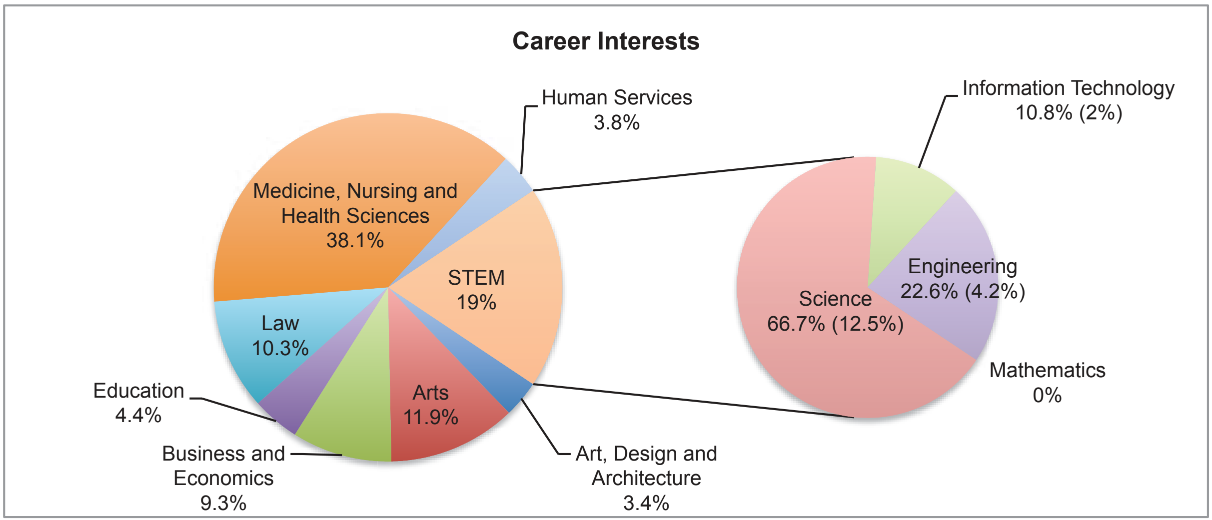

Figure 6: Career Interests

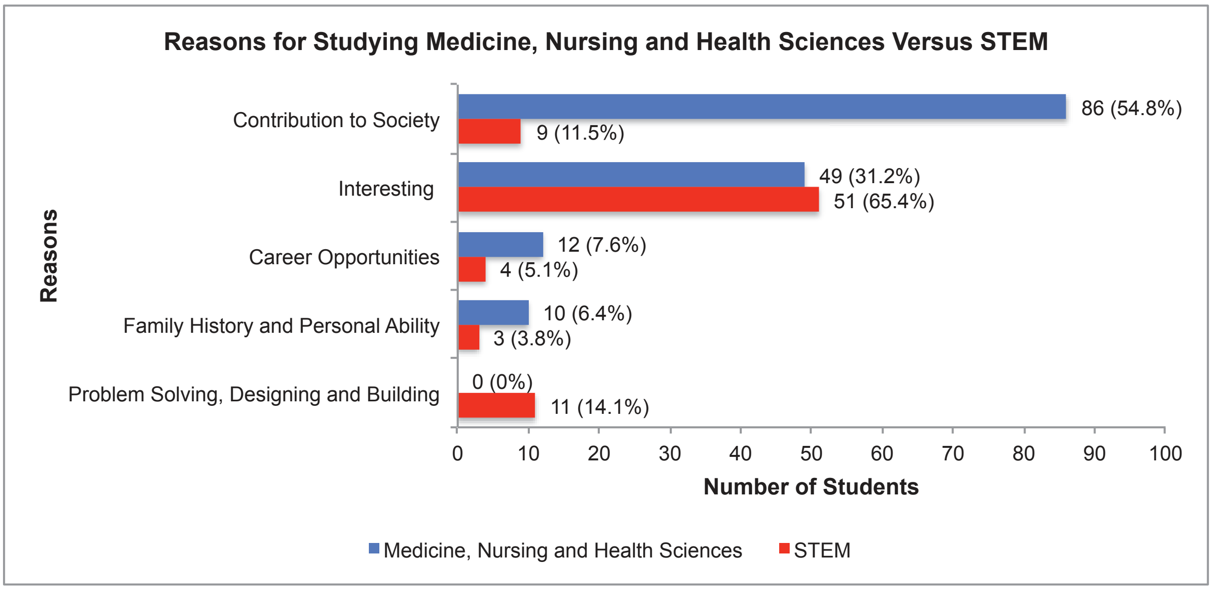

Figure 7: Reasons for Studying Medicine, Nursing and Health Sciences Versus STEM

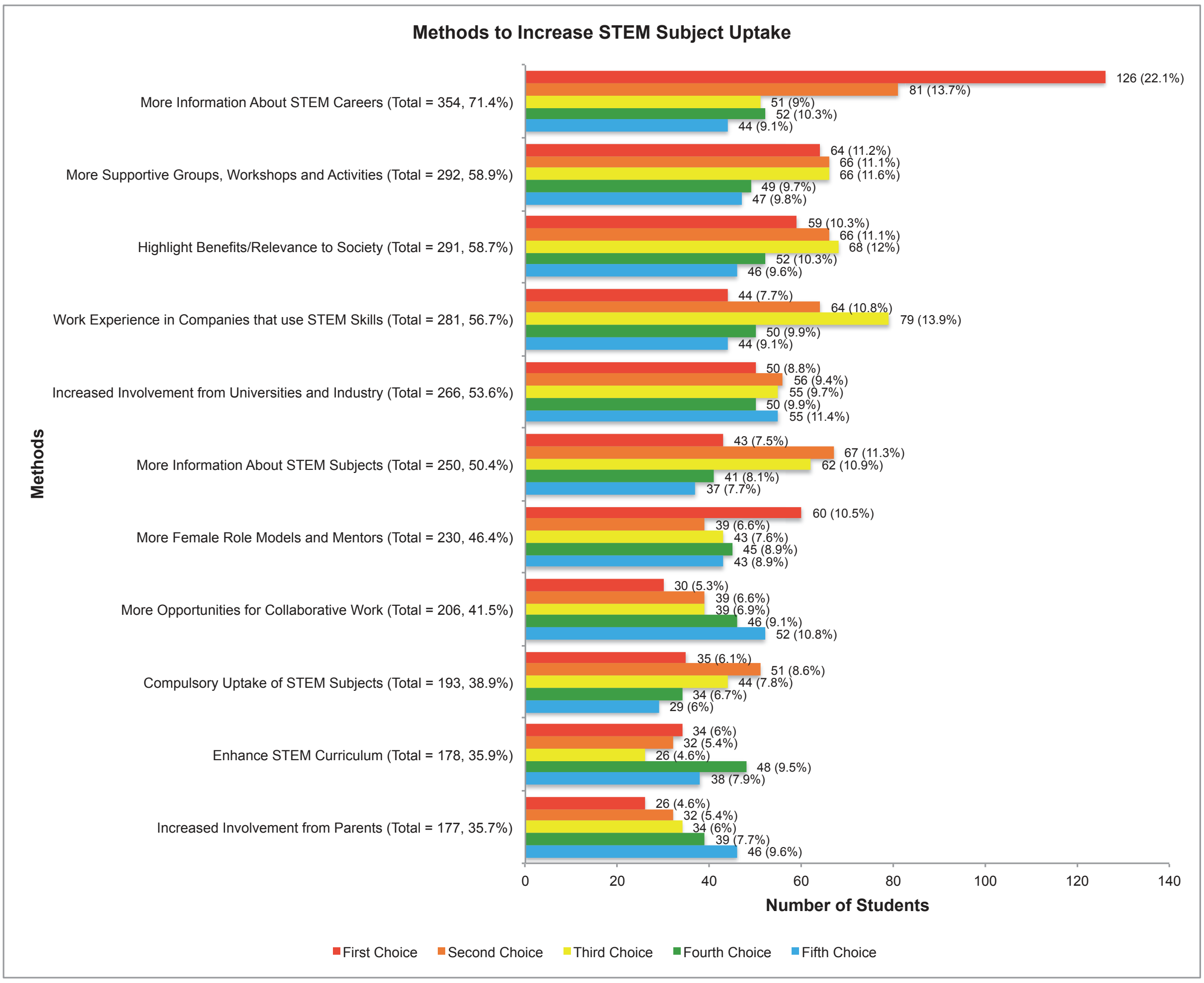

Figure 8: Methods to Increase STEM Subject Uptake

Discussion

The perceived difficulty of STEM subjects and a lack of information about STEM career pathways, remain the dominant barriers to the uptake of STEM subjects, as revealed by 55.4% and 45.1% of students, respectively. Illustrated in Figure 8, 58.9% and 71.4% of students believe that the provision of STEM workshops and information regarding STEM careers, are fundamental to increasing STEM subject uptake, respectively. Given that students who have attended STEM workshops gained approximately 10 times more knowledge about what engineering is and what engineers do, as compared to students who have not attended STEM workshops, future workshop activities may be tailored to highlight the stimulating and diverse career opportunities that are available within the world of STEM, through the pursuit of highly achievable STEM subjects.

Whilst 19% of students desire to pursue STEM professions, medicine, nursing and health sciences, remains the prevailing career aspiration, with 38.1% of students in agreement. The juxtaposition of societal value associated with both careers is confounding, as 54.8% of students associated the latter with great societal value, as compared with a mere 11.5% for STEM. Given that 58.7% of students surveyed identified highlighting the benefits and relevance of STEM careers to society as a method to increase STEM subject uptake, in addition to previous successes in attracting female students through emphasizing just that during STEM workshops (Duffield and Li, 2016), such findings may be applied towards future STEM workshop activities.

92.9% of students regarded family as governing on subject choice. Accompanying workshop materials designed for family members that comprise of information regarding STEM careers and their benefits to society, in addition to upcoming workshop events, may be valuable to support family members and their children to make well-informed career decisions.

Conclusion

While gender stereotypes, a lack of female role models and negative imagery associated with STEM are still frequently highlighted in the extensive body of literature as a cause for the underrepresentation of women in STEM fields, only 6.3%, 9.5% and 2.7% of students supported such claims, respectively. Contrariwise, the perceived difficulty of STEM subjects and a lack of information about STEM career pathways, remain the dominant barriers to the uptake of STEM subjects, as revealed by 55.4% and 45.1% of students, respectively. Societal factors have been established to influence students' uptake of particular subjects, with 92.9% of students regarding family as governing on subject choice. Similarly, due to perceived societal value, medicine, nursing and health sciences remains the prevailing career aspiration, with 38.1% of students in agreement.

The findings from this study suggest that the plethora of gender targeted STEM strategies to remove gender stereotypes and the negative portrayal of STEM, have been successful, at least within this population. However a more thorough exploration into whether such stereotypes and portrayals were ever an issue in the first place, within this population, is required. Furthermore, socioeconomic status and learning methods could be confounding factors in the research. Future studies with students from more diverse types and demographics of schools should be performed to ascertain if these results are anomalous or signal a wider change in student perceptions of STEM from the wider literature.

Perhaps by implementing an amalgamation of the above recommendations we can address the new barriers that surround this complex, multifaceted problem, thereby improving the global gender disparity in STEM disciplines and ultimately, the world's performance and productivity.

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Moral Development of Students Entering the Civil Engineering Bachelor

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CONTEXT Engineering solutions may bring many benefits to society, but could also harm the wider community if engineers do not act ethically. Therefore, engineering educators have the hard task to educate engineers who can use proper moral judgment when making decisions, specially, in situations that involve ethical dilemmas. Similarly, institutions need to assess to what extent their graduates are developing the necessary moral abilities to practice engineering in a socially responsible way. While the international engineering education literature has started investigating these issues, there are still many aspects that needs to be researched in the Australian engineering higher education context.

PURPOSE As part of a larger effort to investigate moral development of engineering graduates, the goal of this paper is to report the developmental level of moral judgment abilities of engineering students entering the Civil Engineering program at the beginning of their second year.

APPROACH To investigate students' moral judgment abilities, we grounded this study in Neo-Kholbergian theory of moral development. Specifically, we distributed the Engineering and Science Issues Test (ESIT) and a demographic survey to students in a large second year civil engineering course at the beginning of the academic year. The ESIT is a scenario-based instrument specifically designed to gauge respondents' moral judgment in engineering practice context.

RESULTS The results of the statistical analysis of students' responses to ESIT questions shows that our subject group had not yet fully developed the higher levels of moral judgment. Additionally, we did not find statistical differences in terms of age, gender, previous work experience, and previous ethics education. Finally, the ESIT scores were similar to other studies that distributed ESIT with similar populations.

CONCLUSIONS Our findings suggest that ethics education needs to be properly integrated in the engineering curriculum to support students to reach higher levels of moral judgment abilities. The consistency of this study findings with other studies also suggest that the ESIT is a rigorous and sound instrument to measure moral judgment of engineering students. Future research should investigate moral judgment levels of students in the final years of their education to understand to what extend engineering programs are providing the needed educational support to develop engineers graduate that can positively impact the wider community.

KEYWORDS Civil Engineering, Ethics, Moral Judgment, Social Responsibility.

Introduction

Although engineers are often regarded as “problem solvers”, recent events like the deepwater horizon oil spill and the Volkswagen emissions scandal remind us that the “solutions” that engineers disseminate into the world may sometimes cause more harm than benefits to human beings and the environment. Therefore, it has long been recognized that engineers should receive ethical education as requested by Engineers Australia (EA) and other accreditation bodies around the world. However, it is not yet clear to what extent higher education is supporting the development of moral reasoning of their graduates.

In fact, most of the studies on moral reasoning to date have focused on the effect of single interventions or courses. For instance, Self and Ellison (1998) and Borestein et al (2010) investigated the gains of moral reasoning as a result of attending a course on engineering ethics. However, no comprehensive study of how engineering students develop moral judgment across their education has been conducted. This is particularly important as research has shown that students commitments to and concern over public welfare decline over the course of their education (Cech, 2013) and that ethics was identified as a “skills gap” in graduates (Jollands, Jolly, & Molyneaux, 2012).

To address these issues, we undertook a longitudinal study to investigate the moral development of civil engineering students. In this study, we present the preliminary results of our first step of the study which consisted of determining the entry developmental level of students starting the civil engineering. Specifically, in this paper, we ask the following two research questions:

1. What is the level of moral development of students entering the civil engineering program?
2. How do students with different background and demographic characteristics differ in their moral development?

To answer such questions, we grounded our study in Neo-Kohlbergian theory and used the Engineering and Science Issues Test (ESIT) to measure students’ moral judgment, as described in the details in the following sections.

Theoretical framework

In this study, we investigate students’ moral reasoning abilities through the lenses of Neo-Kohlberghan cognitive moral development theory (Rest et al., 1999). Such theory is based on Kohlberg’s (1984) original developmental theory. Kohlberg postulated that individuals would go through six sequential self-contained stages of moral development. The Neo-Kohbergian scholars instead substituted the six stages with three schemas (concept borrowed from cognitive development theory), thereby conceiving moral development in terms of shifting distributions of schemas rather than a stepwise progression (details on differences between the two theories are provided in Rest et al. (1999)).

The three schemas of the Neo-Kohlbergian theory are pre-conventional or personal-interest, conventional or maintaining norms, and post-conventional. Individuals who predominantly use the pre-conventional schema will make decisions based on self-interest when faced with ethical dilemmas. Individuals who rely mostly on the conventional schema will make decisions based on laws and norms. Individuals who rely mostly on the post-conventional schema will make decisions based on ethical ideals (e.g., universal rights and social justice).

The most common instrument that has been used to measure development of moral judgment through the lenses of Neo-Kohlbergian theory is the Defining Issues Test (DIT) and its latest version DIT-2 (Rest et a., 1999). The DIT consists of five scenarios that present moral dilemmas followed by two rating tasks. The combination of the two ratings tasks provides scores that indicate the level of moral development of the respondent (Rest et al., 1999). The most appealing characteristic of the DIT is that it has been validated by over 400 studies and has been used in multiple disciplines, including accounting (Abdolmohammadi & Ariail, 2009), veterinary science (Batchelor, Creed, & McKeegan, 2015), pharmacy (Gallagher, 2011) and others (see Center for the Study of Ethical Development (2006)).

Drake et al (2005) used the DIT to evaluate the effect of a short module on engineering ethics and found no significant increase in pretest/postest results. Among the reasons for the lack of significant results, Drake et al (2005) observes that the DIT focus on general, non-engineering situations and may not capture changes of moral judgment of engineering-specific ethical dilemmas. Thus, they concluded by suggesting that "it might be beneficial to develop a new instrument, perhaps modelled on the DIT-2, incorporating ethical dilemmas likely to be faced by engineers" (Drake et al., 2005, p. 229). Based on this conclusion Borestein et al. (2010) developed the Engineering and Science Issues Test (ESIT) to measure moral judgment. The ESIT demonstrated to be a valid and reliable instrument and therefore it was selected for this study as described below.

Methods

In this section, we describe the methods used in the first stage of our larger project to investigate moral reasoning of civil and other engineering students. The goal of this specific first phase was to create a baseline understanding of the moral judgment attitudes of students entering the civil program in the second year and to conduct initial tests of the performance of our chosen instrument to capture differences in moral reasoning levels. This baseline data will then be used in the future to track and understand students' development of moral judgment. Below, we describe the instrument we used, the data collection procedures and participants, and our data analysis approach.

The Engineering and Science Issues Test

To measure students' moral development, we distributed the Engineering and Science Issues Test (ESIT) (Borenstein et al., 2010). The ESIT is an instrument that was modelled after the Defining Issues Test (DIT) and measure the level of moral judgment development in the context of ethical dilemmas faced by professional engineers. Specifically, the ESIT contains six scenarios (one paragraph of length) that present ethical dilemmas in real-life engineering work situations. Here is an example of one of the scenarios:

> Engineer Jameson owns stock in RJ Industries, which is a vendor for Jameson's employer, Modernity, Inc., a large manufacturing company. Jameson's division has been requested by management to cut one vendor: either RJ Industries or Pandora Products, Inc. Pandora Products makes a component that is slightly higher in quality and slightly more expensive than that made by RJ Industries. Management and the other engineers in her division do not know that Jameson has a financial interest in one of the two vendors. Jameson is unsure whether she should participate in the decision. (Borenstein et al., 2010, p. 391)

After reading the scenario, respondents are asked to complete two rating tasks. In the first task, respondents rate 12 questions on the importance to solve the ethical dilemma on a scale of 1 (great importance) to 5 (no importance). In the second task, respondents pick the top four questions and rank them in order of importance. Each of the 12 question is worded to reflect the three schemas of Neo-Kohlbergian moral development theory: 1) pre-conventional (or persona interest), 2) conventional (or maintaining norms), and 3) post-conventional. Example of questions for each schema for the above scenario is reported in table 1.

Table 1. Examples of ESIT questions with corresponding schema

Sample questions	Corresponding schema
Q12. Will Jameson's decision potentially cause harm to the public?	Post-conventional / Personal Interest
Q02. Is it required by law that she report that she owns the stock?	Conventional / Maintaining Norms
Q06. Would disclosing her financial interest help Jameson's career?	Pre-conventional

To evaluate participants' responses to the ESIT, two indexes are traditionally calculated. The responses to the ranking task (i.e., rank the four most important questions) is used to calculated the P-Index, which is a measure of respondents' preference of the post-conventional schema when dealing with ethical dilemmas. The P-index is a weighted average with values ranging from 0 to .96 (60 potential points, but only 58 available) and is calculated as follows:

> P-INDEX = (4 * the number of post-conventional issues ranked first + 3 * the number of post-conventional issues ranked second + 2 * the number of post-conventional issues ranked third + the number of post-conventional issues ranked fourth)/60

The higher the P-Index score, the higher the preference toward post-conventional thinking.

The second index that is the N2-Index. The N2-Index is a measure of respondents' preference of post-conventional schema over the pre-conventional schema. It is calculated by also using responses to the first rating task (i.e., rate importance of all 12 questions). The formula to calculate the N2-index is:

> N2-INDEX = P-INDEX – 3*(average rating on pre-conventional issues – average rating on post-conventional issues)/(standard deviation of ratings on pre- and post- conventional issues)

Like the P-Index, the higher the N2-Index score the more the participants prefer to base their reasoning on the post-conventional schema over the pre-conventional schema.

Finally, in addition to the two traditional indexes (P and N2) we also developed two new indexes that were not used in previous ESIT studies (Borenstein et al., 2010): the C-Index and the PRE-Index. The former is calculated with the same formula of the P-Index but counts the number of conventional questions ranked as first, second, etc. The latter like the C-Index is calculated by counting the number of pre-conventional questions ranked as first, second, and etc. These indexes were added as we were interested to investigate students' preferences for the pre-conventional and conventional schemas as well.

Data collection and Participants

We collected electronically responses to the ESIT from 220 students during the first week of the first semester of 2017. Data was collected from two courses: course A and course B. Course A is a new 2-unit mandatory course focused on environmental issues and professional ethics (Murzi et al., 2017). Course A was developed starting from a 1-unit course that was taught in the previous years and was redesigned to include the professional ethics component. Course B was instead the 1-unit equivalent of Course A that was offered to repeating students from previous years and did not have the ethics component. In addition to ESIT, we also collected demographic information that we used in our analysis to compare across groups.

Data analysis

After calculating scores of the four indexes (P, C, PRE, N2) for all participants, we used Welch t-tests to compare average scores among groups. First, we compared means index scores of Course A students with Course B students. Second, we compared our results with other studies that used ESIT, although in this case we were not able to perform any statistical test. After these two first steps, we focused our analysis on Course A students who are more representative of the types of students starting in the program (being Course B student repeaters). Third, we compared Course A students based on the demographic characteristics. Finally, we ran the same analysis for Course A with Australian students only, as ESIT was proven to be sensitive to language ability due to its extensive reading requirements.

Findings

The first set of results concerns the mean scores across the four indexes for students in Course A and Course B as reported in table 2. The results show that students in both courses demonstrated higher preferences for post-conventional and conventional rather than pre-conventional schemas. This suggests that the participants of this study already started with fairly well-developed moral reasoning skills. Furthermore, the P-Index scores of Course A students were significantly lower than Course B students, and Course B students had also a lower score on the C-index than Course A students. This suggests therefore that course B students were slightly further advanced in their moral reasoning development. Such a result should not be surprising since Course B students had more time to develop their skills.

Table 2. Overall scores for experimental and control group

	N	P-Index	C-Index	Pre-Index	N2-Index
Course A	146	0.474	0.381	0.118	3.098
Course B	74	0.509	0.336	0.127	3.015
Difference		-0.035	0.045	-0.009	0.083
P-value		0.0328	0.0046	0.5399	0.6623

As a second step, we compared our results to other studies that used ESIT to check for consistency of results with similar population. In their study, Borenstein et al. (2010) used the ESIT in a quasi-experimental approach with pre- and post-tests with control group study. The majority of the students enrolled in their experimental and control courses were junior and senior, therefore one or two years ahead to the students enrolled in our courses. Skinner and Bushell (2013) distributed the ESIT to their students in the undergraduate courses “EL41” and “CE40” in an Australian university, at the beginning and end of the semester. The pre-test averages from both studies are reported in Table 3. The scores from our study and the other studies are very similar, suggesting that the moral development abilities, as measured by the ESIT, are quite similar for bachelor engineering students across countries.

Table 3. Comparison with other studies that used ESIT

	This study		Borenstein et al (2010)		Skinner & Bushell (2013)	
	Course A	**Course B**	**Exp.**	**Contr.**	**EL41**	**CE40**
P-Index	0.474	0.503	0.505	0.479	0.490	0.510
N2-Index	3.100	3.010	2.970	2.590	2.940	3.03

After looking at overall scores, we unpacked in more details the performance of the Course A students, who provide a more accurate representation of students entering the civil engineering bachelor program than Course B students, as Course B students had been in the program for longer time. Specifically, we analyzed Course A students’ results based on their demographic characteristics. In this analysis, we focused solely on the scores of the two traditional indexes, P and N2. The results are reported in Table 4 and Table 5. The Welch t-tests show that 18 years old students scored significantly higher than their 19 and 20 years old classmate both for P-Index and N2-index. Likewise, Australians scored higher than internationals on both P- and N2-Indexes and natives scored higher than non-natives English speakers on both indexes. These results suggest that age, nationality, and language ability may influence students' moral reasoning. Additionally, female students scored significantly higher of males on N2-Index, while students with no prior ethics education scored higher as well on N2. These suggest that female students have stronger tendency toward post-conventional thinking over pre-conventional as compare to male students. However, previous studies have shown that the ESIT and DIT are particularly sensible to English ability due to the increased reading ability requirements. Therefore, the results could be mostly influenced by English ability rather than other factors.

Table 4. Demographic differences in P-Index for Course A students

Group1			Group 2			P-Index differenc e
	n	P-Index		n	P-Index	
Male	98	0.468	**Female**	47	0.488	-0.020
18	55	0.507	**19**	43	0.457	0.050*
18	55	0.507	**20**	20	0.438	0.069*
18	55	0.507	**21**	10	0.452	0.055
18	55	0.507	**22+**	18	0.463	0.044
3Sem<	116	0.475	**4Sem+**	30	0.469	0.006
Prior Ethics Ed	123	0.514	**No Ethics Ed**	23	0.466	0.048
Prior Work Exp.	18	0.439	**No Work Exp.**	128	0.479	-0.040
Aussie	93	0.492	**Internationals**	47	0.446	0.046*
Native English	96	0.485	**Non-natives**	50	0.445	0.040*
						**p <0.05*

Table 5. Demographic differences for N2-Index for Course A students

Group 1			Group 2			N2-Index Difference
	n	N2-Index		n	N2-Index	
Male	98	2.97	**Female**	47	3.43	-0.46*
18	55	3.50	**19**	43	2.88	0.62*
18	55	3.50	**20**	20	2.65	0.85*
18	55	3.50	**21**	10	2.79	0.71
18	55	3.50	**22+**	18	3.06	0.44
3Sem<	116	3.10	**4Sem+**	30	3.09	0.01
Prior Ethics Ed	123	3.03	**No Ethics Ed**	23	3.42	-0.39*
Prior Work Exp	18	3.14	**No Work Exp**	128	2.77	0.37
Aussie	93	3.38	**International**	47	2.66	0.72*
Native English	96	3.32	**Non-natives**	50	2.67	0.65*
						**p <0.05*

To verify whether the results table 4 and 5 were only due to English ability, we separated the 96 native English speakers and ran the same t-tests for this specific group only. The results are showed in tables 6 and 7. The lack of significant results in P-Index differences suggests that the significancy shown in the above table was primarily due to the participants English ability. However, the fact that gender and prior ethics education continues having an effect on participants' moral reasoning even when focusing only on native English speakers, suggests that such factors are very important in the moral development of students.

Furthermore, it still remains to investigate further why the students that did not have prior ethics education scored higher on the N2-index. One possible reason could be that the types of educational interventions that students received prior to data collection did not emphasize post-conventional reasoning and may have focused on rules and regulations, thereby fostering a more conventional mindset.

Table 6. Demographic differences for P-Index for Course A native English speakers

Group 1			Group 2			P-Index Difference
	n	P-Index		n	P-Index	
Male	69	0.488	**Female**	26	0.495	-0.007
18	50	0.504	**19**	28	0.478	0.026
18	50	0.504	**20**	7	0.476	0.027
18	50	0.504	**21**	5	0.497	0.007
18	50	0.504	**22+**	6	0.422	0.081
3Sem<	78	0.490	**4Sem+**	18	0.482	0.008
Prior Ethics Ed	16	0.485	**No Ethics Ed**	80	0.509	-0.025
Prior Work Exp	85	0.459	**No Work Exp**	11	0.493	-0.033

Table 7. Demographic differences for N2-Index for Course A native English speakers

Group 1			Group 2			N2-Index Difference
	n	N2-Index		n	N2-Index	
Male	69	3.19	**Female**	26	3.78	-0.59*
18	50	3.57	**19**	28	3.06	0.52
18	50	3.57	**20**	7	3.21	0.37
18	50	3.57	**21**	5	3.51	0.06
18	50	3.57	**22+**	6	2.42	1.15
3Sem<	78	3.34	**4Sem+**	18	3.26	0.08
Prior Ethics Ed	16	3.30	**No Ethics Ed**	80	3.42	-0.12*
Prior Work Exp	85	3.24	**No Work Exp**	11	3.33	-0.09
						**p* <0.05*

Conclusions and Future Research

In this study, we presented the preliminary results from our longitudinal study. The goal of this study was specifically to determine the characteristics of our baseline that we will use to compare the results of future research. For our baseline, we had two groups of students: those enrolled in Course A, a new mandatory course on environmental issues and professional ethics, and those in Course B, a smaller offering of Course A for repeaters. There were four main takeaways from our findings. First of all, students in Course B started with higher levels of moral reasoning. Given that students in course B had been in the program for longer time, the results suggest that the learning experiences they had until then helped them improve their moral abilities. For our next research steps, it will be very important to track how changes in moral reasoning are affected by the different learning activities implemented in the two courses.

Second, we found that female students in course A started with higher levels of moral judgement as compared to males. This result is in contrast with Borenstein et al. (2010) who instead found no significant difference in pre-test scores among gender. Therefore, it needs to be further investigated the effect of gender on moral development and in our next research we will need to keep gender in consideration in all statistical analysis. Third, it is clear that

English abilities may affect the results of ESIT as, previously found by Borenstein et al. (2010). This effect is specifically due to the long reading requirements of the test, which may make it difficult to complete for those who struggle in English reading comprehensions. Consequently, it is advised to distribute the ESIT only to English native and advanced level speakers or to exclude non-English speakers from analysis. Finally, it was interesting to see that students who had not had prior ethics training scored higher on the ESIT. Since we do not have specific details on their previous experience, it is difficult to establish the underlying cause of this result.

In sum, as we continue our longitudinal study, we will have to be especially aware of the effect that gender, English proficiency, and previous ethics learning experience many have on our results. Similarly, we advise that scholars interested in using ESIT or similar instrument to investigate moral development pay particular attention to these details when collecting data for their studies.

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Refocusing the architecture of assessment, learning and teaching

Refocusing marking practices to enculturate learning: developing a practice architecture

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C1: Integration of theory and practice in the learning and teaching process

CONTEXT

In a design engineering and professional practice core, which is embedded in each of the four levels of undergraduate engineering, the need to develop more sustainable marking practices has become increasingly apparent. This need is particularly evident within professional practice, including engineering communication, as the marking is particularly time-consuming for many aspects of these courses. To address this need, a far more multi-layered, team-orientated approach is required to ensure succession as teaching staff leave, provide consistency of grading for the students and ensure that teaching and learning lie at the heart of the marking process. To achieve this, a team of twelve markers, from 2nd year undergraduate through to postgraduate levels, has been brought together. This range of markers enables the development of a team that can evolve cohesively and be fully trained and moderated. This process seeks to build a bank of expert, inclusive markers who can 'buy in and out' of the marking schedule in accordance with their own learning schedules, enabling us to both mentor and promote marker skills and to support our best markers. Simultaneously a practice architecture for marking is being developed, which continues to support students through the assessment processes of each course, whilst strengthening the connection between the students and their teachers.

PURPOSE

This study is designed to examine the effect of varying practical elements of assessment architecture as a method of integrating continuous teaching and learning into assessment.

APPROACH

To mirror the cohort, we selected a diverse range of successful engineering students from 2nd year undergraduate to 1st year postgraduate levels, to mark into a L1 course on writing in the first instance. Professional Practice reoccurs in L3 and Honours but L1 is our trial ground. We have begun the process of examining the practice architecture of marking, our aims and objectives and devised a new system of approaching marking using questions to challenge those being assessed rather than taking a more traditional deficit approach. The system is designed to be swift and effective for all stakeholders, enabling us to make marking part of the learning process, as well as an efficient approach to returning the marks to the students.

RESULTS

We have evaluated our philosophical approach, levels of inclusion, types of student response, depth and efficiency of marking and the impact of a marking load on the well-being of the markers, using instruments such as short surveys and semi structured discussions.

CONCLUSIONS

We feel confident that reviewing the architecture of our practice will enable us to build a bank of confident, secure markers who mark to level. We also have confidence that the students receiving the type of feedback we are proposing will gain clear advice and support for their ongoing learning in professional practice.

KEYWORDS

Teaching and Learning, Assessment, Practice Architecture, Well-being

The Introduction

This year, to address the need to develop a successful, engaged marking team, to continue to increase the quality of marking and to encourage the recipients of the marking to engage fully with the advice offered, a new practice architecture of engagement and delivery of assessment within a Level 1 Professional Practice course has been explored. The chosen course for the pilot testing was an introductory course for Mechanical engineers.

The levels and style of marking will then be reviewed and expanded to cover the related Professional Practice courses throughout Levels 1 to 3, in time impacting significantly on the Honours level enactment of Professional Practice. Whilst the course has been revised from a contents perspective, as it is annually, it was important to the team to place assessment practice at the heart of learning and teaching rather than being purely summative, thereby creating an impact that goes beyond the immediate assessment piece.

The vision of assessment sought is that it is dynamic, replicable and, above all, not only summative assessment *of* learning (the university requirement) but formative assessment *for* and *as* learning (the learning and teaching driver for the course), with the facility for improvement put firmly onto the students who carry their individual learning forward into future, aligned courses. The practice architecture of assessment is envisaged as what Kemmis (2008) calls a "mediating precondition", designed to frame, upscale and shape learning, rather than simply define current learning without any design for progression of learning and practice. Thus, from the outset, the embedded protocols were designed to be inherently developmental and reviewable. Critical also was the desire for the processes and practicalities of assessment to be sustainable and supportive of the well-being of the markers: that is, enabling the development of an ongoing team of markers who could then themselves train new recruits in due course, developing reliability, consistency and engagement with this critical discourse.

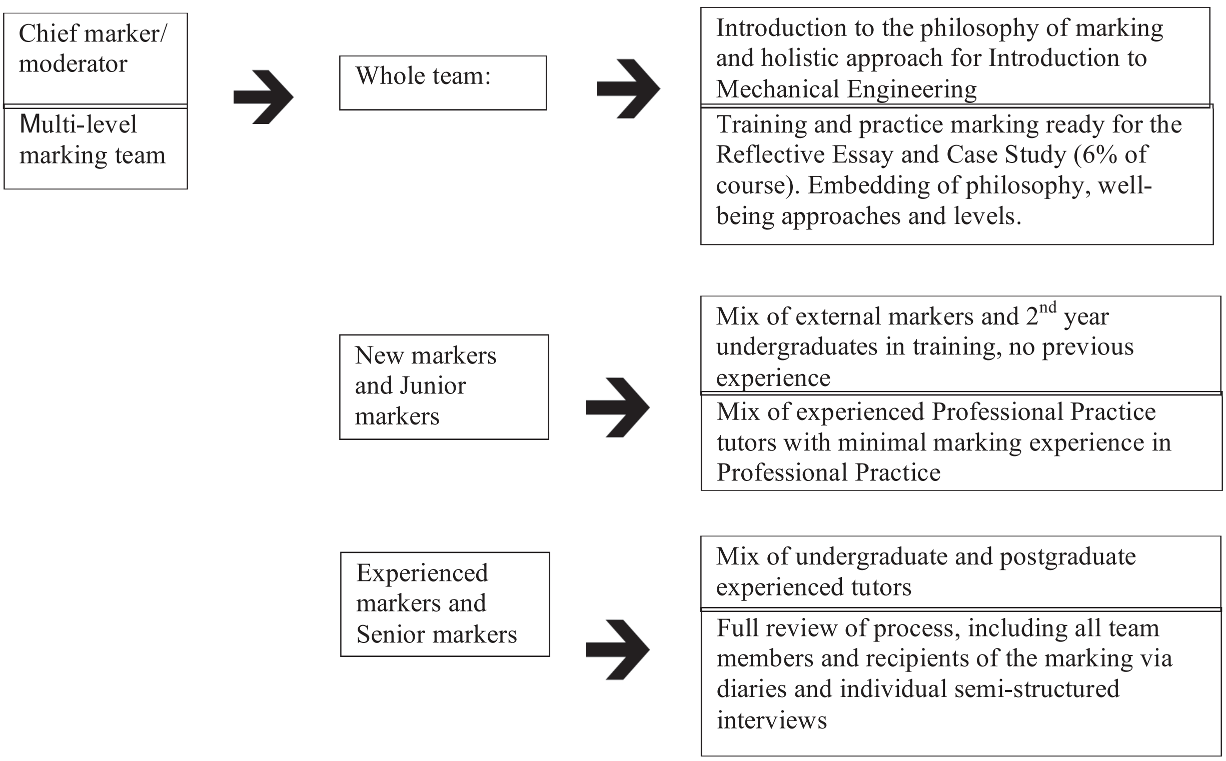

Figure 1: Schematic of Marking Training as an iterative process (paralleling the Engineering Method) (Hunter and Missingham 2017)

Whilst in previous years, teams of (primarily) undergraduate and (occasionally) postgraduate markers have been employed, the teams have been small and can be affected by the timing of assignments of the markers' own. Clearly, a large enough team that some would always be available and supported by more experienced markers was important to avoid issues of marker overload. However, the more markers there are in the team, the more variations in understanding of rubrics and applications of grade boundaries are possible.

A team that feels confident in its skills and interchangeable is therefore ideal, so that marking can be undertaken with consistency, despite the fluctuating membership of each team for individual marking projects and the varying numbers of markers involved. This breadth of knowledge also protects younger, less experienced, markers from being overwhelmed by the sheer volume of marking to be covered and simultaneously builds confidence and skills. Important also was to ensure that the new practice would be both reviewed and embedded in practice, a feat rarely achieved in a world of innovation overload (Goodyear, Casey and Kirk 2016). An approach that is transformative and sustainable at a deeply individual, as well as an institutional level, was therefore sought (Freire 2005 in Yagalski 2012).

The Approach

The approach incorporated developing a philosophy of marking (marking as assessment using Socratic questioning), a philosophy of marker support (well-being practices), selection of the individual members of the team and mechanisms for reviewing the process (structured tinkering). Selection of the marking team was the first critical task: it was important that this team reflected the cohort of Engineers, was confident in its own professional practice skills and felt empowered to make judgements about the writing of the new cohort.

Once the team was selected, balanced to reflect the gender, language and cultural elements of the cohort, training was begun. The training involved a strong time and task framework designed to protect the markers from stress and overwork. Whilst being rigorous in the clarity of its demands and having a didactic purpose for the recipients, the framework also involved discussion, seeking both understanding, personal involvement and ownership from each stakeholder (student markers, student learners and lecturers). Views were sought, shared and brought into the framework through a series of training meetings which were as egalitarian in nature as possible. The details of the training sessions were vital to this process and included running the training in the student learning Hub, to ensure the markers were comfortable and felt ownership of the training space, thereby encouraging them to take an active role in the process of marking, even before pencil was put to paper (Salomon and Perkins 1988).

The first element established was the academic purpose of the assignment. The training document explains that “the students have been given this assignment to test their understanding and knowledge of the Engineering Method, report writing skills, ability to write in the expositional style, ability to find appropriate case studies and their ability to write citations correctly. This is a complex task and the variant drivers are all written into the rubric to support both the writers and the markers” (Hunter 2017). This form of testing drives the need for an holistic assessment that produces a final grade, an assessment of learning, that will stand as part of each student’s degree and it provides rigour, purpose and authenticity to the marking. It also supports understanding an application, at a first-year level, of developmental forms of reflective practice (*as per* Dowling, Carew and Hadgraft 2013).

The framework for the responses, however, is also socio-affective, as is reflected in the reminder that “the work has been completed and handed in, on time, in almost all cases. The students are now looking for a response”. It was felt important to remember not only abstract standards, which need to be upheld to ensure the degree ultimately has value in the market-place, but that real people are at the beating heart of the process. Some 260 of the nearly 300 students in the cohort handed this assessment piece in. Each of those 260 people, therefore, valued their learning and degree sufficiently to complete a challenging task and develop their professional practice skills. The markers agreed that the responses given should give respect to that achievement through the wording of the individual responses, which need to indicate that each individual assignment has been taken seriously and considered for its merits, as well as including suggestions about how to improve the skills set of the individual recipient further. This philosophy drove the need to include assessment for learning, as well as assessment of learning: it is a way of honouring that effort and dedication on the part of the student and recognising the diligence they have shown. It was also felt important to encourage the 40 students who chose not to complete the task to reconsider this position and the role of professional practice within their Engineering degree.

Thus, as part of this transformative praxis, the team has sought to include a tri-partite approach to assessment, covering all the elements of teaching and learning available through this course, generating, explicitly: "a) A mark which will go on the students' transcripts, providing them with summative evidence of their achievement in this course. This is called Assessment *of* Learning; b) Feedback which will enable the students to improve on later, similar tasks and provide a form of dialogue for them so that they understand their own strengths and weaknesses and know what to do to improve their work. This is called Assessment *for* Learning. It is formative in nature and should support learning; and c) Formative feedback that enables the students to feel good about their achievements and engaged with the learning process. This is crucial for well-being, positivity and engagement. This is also Assessment *for* Learning and is delivered through the wording of each marker's responses, which are designed to be helpful, affirmative and emotionally supportive".

Through this process, the markers should also gain deeper understanding of the issues raised by the task and this knowledge will then be fed back to the task setters, rubric creators and future markers to complete the assessment loop and enhance the experience of teaching and learning for all the participants in the course: learners, teachers and markers. It is this feedback loop that should enable the process to become both transformative and embedded in the praxis of professional practice, and reflective of the approaches and skills which we seek to inculcate in our students and student markers. Meanwhile the recipients of the marking should feel empowered to make positive adjustments to their learning, grow as learners, and develop further their independent learning skills, through ownership and management of their tasks and assignments.

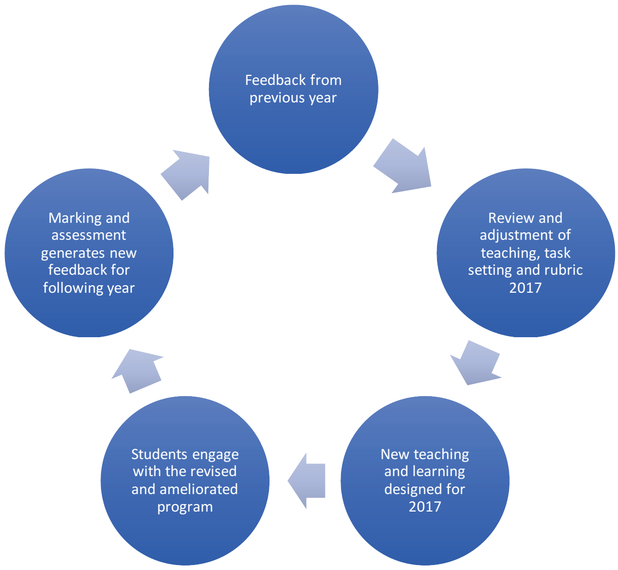

Figure 2. Image of the feedback loop of assessment for learning and teaching (Hunter, 2017).

As educators, the leaders of this team and each member of the marking team believe strongly in exploiting every learning opportunity that is available. Whilst marking drafts and offering individual discussions about the marking decisions would be exemplary, the fact some 300 scripts must be marked within two weeks to comply with university regulations and the moral imperative to return work in a timely fashion, is a huge constraint which makes such an approach impossible to achieve. Thus, this methodology is designed to create not only a form of dialogue but also a way to give responsibility back to the student to manage their learning, is by responding with a form of Socratic thinking: by offering questions instead of comments or closed remarks.

The Experiment

Socratic thinking is based around six types of question forms, all of which are designed to produce problem based thinking, or recipient solutions. The first type of question is questions for clarification, the second is questions that probe assumptions, the third is questions that probe reasons and evidence, the fourth is questions about viewpoints and perspectives, the fifth is questions that probe implications and consequences and the sixth is questions about the question. The types of questions being asked are built into the table of guidance questions below to show that the full Socratic range can be used in response to the assignment, to engage the recipients of the marking as fully as possible (University of Michigan 2017). To achieve this desired outcome, therefore, the markers were asked to respond with questions, rather than other forms of comment. Attention was also drawn to the ways in which the questions change in nature as the marker moves through the elements of the rubric.

Sample Initial Assessment Comment Bank for Markers.

Motivation, context and proposition	**Question Types: 1, 4, 6**
Could you usefully add more context in terms of the reasons for the case, the situation in which the decisions were made and the reasons why the case is important in your view?	Could you think carefully about how to make your proposition statement clearer? Could you make it shorter/more direct/simplify it to find the essence of the problem?
Have you got a clear thesis statement in this paragraph?	Could you link the case more clearly to the argument?
Could you revise your word choices here so that the writing becomes more technical?	Could you consider the tense here, so that it is logical and sequential?
Background detail and technical information	**Question Types: 1, 2, 3, 4, 6**
Have you used sufficient Engineering language here to convey the detail of your case?	Have you checked the spelling of unfamiliar words?
Have you linked details/events and specifications for the technical aspects of your case?	Have you made clear in your wording which is primary information and which is secondary to your case?
Discussion and analysis	**Question Types: 1, 2, 4, 5**
Could you link your argument more closely to the Engineering Method?	Could you move to discussion from recount of events?
Could you move to commentary, where you express your own opinion, as well as a range of others' opinions?	Could you look at your analysis and see if you could analyse in a range of ways, e.g. in terms of the process, the Engineering Method and the outcome(s) of your chosen topic?
Level of Reflection	**Question Types: 1, 2, 3, 4, 5**
Could you take this from a descriptive view to a personal reflection?	Could you include the traits of Engineers here to deepen your analysis?
Could you provide more justification from the case study for your views (i.e. move from simple review to deeper analysis)?	Could you offer ideas about professional development for those in the situation of the case study or seeking to learn from it?
Knowledge of engineering concepts presented in class and integration with case study	**Question Types: 1, 2, 3, 4, 5, 6**
Have you included Engineering concepts?	Have you integrated the Engineering concepts you have identified into your discussion?
Have you picked the most appropriate Engineering concepts for the issue you are discussing?	Does your discussion really include the following elements: explaining and interpreting, exemplifying, comparing and inferring information on engineering concepts? Do you select information clearly and present it succinctly? Do you offer good examples from the core text that support your ideas?

Expositional Structure	**Question Types: 1, 3, 4, 5**
Do you have a clear introduction with a clear set of thesis statements and an outline of the key issues for your discussion?	Do your body paragraphs really take one concept at a time, following a clear pattern, logically and persuasively?
Do you link everything together neatly at the end in a succinct summative conclusion?	Do you have clear topic sentences in each paragraph that act as a road map to the case study?
Have you used analysis in each body paragraph? Is it layered? Is it locked onto the Engineering Method?	Could you improve the cohesion in your writing either across the assignment as a whole, or within its sections?
Formal language/ grammar/spelling; concise, succinct expression (including depth of meaning)	**Question Types: 1**
Have you avoided all contractions and all colloquialisms?	Is your grammar accurate, particularly the use of tense and voice?
Is your work sharp, technical and to the point, cutting out all irrelevance?	Is your spelling accurate, especially for all technical terms?
Referencing and Evidence	**Question Types: 1, 6**
Have you included at least three pieces of textual evidence to support your argument?	Have you included in-text references?
Have you included at least three elements of accurate Harvard referencing at the conclusion of your writing?	Have you used referencing and evidence skilfully to advance and support your argument?
Formatting and Presentation	**Question Types: 1**
Are all the parts of your assignment present, including the cover and mark sheets? Have you signed to say you have avoided plagiarism?	Have you made clear in your wording which is primary information and which is secondary to your case?
General Comments	**Question Types: 1, 2, 3, 4, 5, 6**
Review for word choice.	Review for word form.
Have you made clear in your wording which is primary information and which is secondary to your case?	Is this logical? How might it be improved? Go back to the order you created in your introduction and check everything matches up.
Is this the most important idea? If not, could you include it somewhere else or leave it out so you have more room for reflection/analysis?	Do you have a verb in this sentence? Is the verb in this sentence in the right tense?
Might you have included personal/professional reflection here?	Is this an Engineering term?
Check your word order here so as to maximize the impact of your writing.	Does the reader know the case as well as you do at the end of this report?
Have you used punctuation for effect? Have you avoided comma splicing?	Have you avoided journalese? Do the verb and its subject agree in number and form?

Each of these suggestions is derived from prior experience of marking this course and is designed to support the development of appropriate Socratic choices, to stimulate thought and action on the part of the recipient, the student whose work is being marked. Ferreira and Ferreira (2015) reinforce this approach, demonstrating that Socratic questioning can be used for "professional socialisation … teaching professional values … may enable students to eventually develop into reflective practitioners". The process of change is designed to be incremental and highly focused, using the theory of Structured Tinkering, which allows step-by-step change to become a powerful tool for creating and embedding authentic change (Vossoughi and Bevan, (2014).

The Results

The student markers responded strongly and positively both to the training and the format of the responses suggested for assessing this assignment. That said, some issues were raised by the markers and recipients of the marking. The markers kept marking diaries throughout the process to create a dialogue with the lead marker and feed into development and training for the next round of structured tinkering. These diaries revealed that, despite the clarity of the rubric, there were content issues with the work, focused around actually including elements such as the Engineering Method or formatting references correctly. In terms of assessment, these were easy to point out and remind students of the constraints of the piece.

More challenging in terms of the marking were issues surrounding accuracy and style and the point at which a script becomes so poor in terms of both expression and genre that it should fail. For many undergraduate markers, it felt “unfair” (Marker 3) to fail someone whose English is poor because they are an international student. Ultimately the decision is subjective: the rule that was agreed was that if the reader could not understand the work, it would fail. It had already been established that failing to attain control of the genre was an automatic fail, so this aligned with an established marking constraint.

This question had a corollary, however: to what extent should errors of expression be pointed out in the marking? The spread of responses will need to be addressed in the next training sessions for consistency. There was also some feeling that the Socratic questioning ultimately became limiting rather than enabling. As Marker 5 put it, “saying ‘have you provided an introduction?’ sounded sassy”. It was felt necessary, having established Socratic questioning as the core response, to have the freedom to make statements where clarity would be enhanced, as it would in this case, without sounding aggressive. Thus, in this round of marking, it has been a conscious decision to explore the limits of Socratic questioning as well as the benefits in the marking and consider how to use it to the greatest effect, without it becoming limiting in and of itself.

In terms of how the team were supported (a core focus was on the well-being of the markers), this system indubitably worked effectively. Many of the markers commented explicitly in their diary feedback that they felt supported by having a team leader who kept in clear, regular contact with them. They formed sub-groups and moderated within those sub-groups, which was very positive, and made the final sample moderation significantly easier and faster. The undergraduates liked being invited to shared marking sessions with the postgraduate students and felt valued as a result (they were invited to join the Postgraduate *Shut Up and Write* group). They commented consistently that they liked the training process, which included looking at sample marked papers to start to develop levelling. They found the comment banks and marking codes very affirming and genuinely time saving. They also genuinely felt included in the process and that it was, indeed, a co-operative learning environment. The level of positivity about the process and the deep understanding that this was an on-going, embedding process was most pleasing. The students felt that the connections between the rubric and the assessment outcomes and details were clear and gave clarity to the final grade given; they loved marking in pencil so they could make changes easily. They also affirmed and celebrated the written and spoken reminder to give both constructive and supportive comments.

For all the markers, marking in a team meant the new markers were never alone, “the act of writing questions on their reports rather than direct corrections feels risky, because I know most students will not understand exactly what I want them to do, but I also realise the ones that do will get much more out of it”, was one affirmatory comment (Marker 8). Another was, “understanding how important communication is, having read a load of papers I could barely understand, made me see how vital these communication courses are for professional practice and helped motivate my marking” (Marker 4). The markers saw this process as invaluable for their own learning, as much as for those whom they were trying to help through their marking protocols and so, for the entire team, this experience was affirmation that the protocols were indeed worthwhile.

All the marks were moderated by taking a sample to check. The sample consisted of the two top and two bottom grades and two papers either side of each grade boundary. The consistency of the marking was evident. Not unexpectedly, the next round of training needs to focus on the credit band which contained the greatest numbers of discrepancies, though even here the margins of error are pleasingly narrow. The fails and scrape passes are perhaps the easiest to locate, as are the very good and excellent papers falling into the D and HD bands. As always, the middle band contains the greatest number of variations. This, then, is the key training focus for the new round of marking.

The other element of this process and to close the loop, is a consideration of the perspective(s) of those being marked. There were no complaints about the marking and no grade challenges from any of the cohort being marked. Whilst high levels of challenge are not routinely experienced at the University of Adelaide, some challenges do eventuate. This silence suggests that the students were at least accepting of the marks and could see from whence they derived. A small sample of students were interviewed via semi-structured informal interviews about how they felt about the marking and the comments were strongly indicative that they were keen to learn from the marking and that whatever their grade (Recipient 1 had obtained an HD, for example), they actively sought to learn how to improve. This suggests that this level of detailed marking is valued by all stakeholders (markers, educators and recipients) and so should be embedded and not remain experimental for Professional Practice courses.

The Conclusion

Overall, the structured tinkering approach would appear to have added value to the marking process and ensured that assessment falls within the teaching and learning category, in and of itself. All stakeholders see value in the new approach and so would like it to be embedded in practice throughout professional practice, if not beyond. For us, this is an ongoing, exciting task of structured tinkering which will enable us to design follow-on courses which have embedded value in all elements, and allow us to build a sustainable team of markers to support learning through assessment practices, alongside the direct teaching of the course.

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Simulating Work-Integrated-Learning (WIL) – Learning from Health Professional Education

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SESSION S2: Educating the Edisons of the 21st Century

CONTEXT The use of simulation is gaining prevalence in a number of educational fields, including engineering education in the area of work-integrated-learning (WIL). Despite the utilisation of simulation as an educational strategy, the uptake of simulation in engineering education is incomparable to how it has been undertaken in health professional education. It is proposed that simulation is an educational strategy that can be harnessed further within engineering education.

PURPOSE The aim of this paper is to propose that scenario-based simulation and the Simulation Cycle, which have been developed within health professional education, can enhance the implementation of simulated WIL in engineering education context.

APPROACH The paper takes a theoretical approach by discussing existing applications of simulated WIL within engineering education. Current issues and limitations are identified. A discussion on how these issues can be addressed via the use of scenario-based approach using Simulation Cycle is discussed.

RESULTS It is proposed that 3 key areas of issues exist in the use of project-based simulation. These areas include i) issue of control and coordination of elements (including of human players) within the simulation to achieve learning objectives, ii) balancing industry's involvement and time required from them and iii) managing cognitive overload. In addition, the challenge of engaging students in meaningful reflection is also raised. It is suggested that the use of scenario-based simulation and Simulation Cycle can manage these issues.

CONCLUSIONS The authors are currently developing simulated WIL using the principles proposed in this paper. The focus of the simulation is on problem solving, specifically on the development of appropriate skills for problem analysis.

KEYWORDS Simulation-based education, simulation-based learning, simulation cycle, problem solving, work-integrated-learning

Simulation learning opportunity

The use of simulation is gaining prevalence in a number of educational fields, including engineering education. This is evident in research within engineering education that report the implementation of varied simulation-based learning (Arastoopour, Chesler, & Shaffer, 2014; Arastoopour, Shaffer, Swiecki, Ruis, & Chesler, 2016; Chesler, Arastoopour, D'Angelo, Bagley, & Shaffer, 2013; Davidovitch, Parush, & Shtub, 2006; Jollands, 2015; Lindsay & Good, 2005; Lindsay, Liu, Murray, & Lowe, 2007; Masethe & Masethe, 2013; Ponsa, Vilanova, & Amante, 2010; Prince, 2006; Zou & Chan, 2016). Despite the utilisation of simulation as an educational strategy, the uptake of simulation in engineering education is incomparable to how it has been undertaken in health professional education.

The use of simulation is commonly implemented as an educational method within health professional education. In health, the simulation industry is a billion-dollar business and is increasingly embedded in health services and education. Within this field, simulation education itself can be considered as a discipline. Using simulation for optimal impact requires specialised skills and in Australia, the government has funded a national training program to support health professionals learn to use the method effectively, National Health Education and Training in Simulation or NHET-Sim (The NHET-Sim Monash Team, 2012). The healthcare simulation education community has also matured to include specialist societies, journals, standards of practice and conferences.

Gaba (2007) defined the method as “a technique to replace or amplify real experiences with guided experiences, often immersive in nature, that evoke or replicate aspects of the real world in an interactive fashion”. Simulation can be used as assessment or for improving the learning experiences of students (Adamo, 2003). When used to improve learning experiences, simulation can give students applied problem based learning opportunity (Fanning & Gaba, 2007). Fanning and Gaba (2007) also believed that simulation can result in sustained learning as it requires the learner to be actively engaged in the process cognitively and emotionally. Cheong (2010) identified that the use of simulation can provide a learning opportunity that students may not have in the real world.

Nestel et al. (2014) found that “there is strong evidence for simulated learning technologies leading to increased knowledge and improved skills under specific conditions for several core graduate outcomes in health undergraduate curricula, when compared with no intervention” (p. 6). The positive impact of simulation-based learning on self-efficacy, including within engineering education, is often reported in studies (Cheong, 2010; Jollands, 2015; Zou & Chan, 2016). Given the overwhelming evidence that simulation can enhance learning, it is proposed that simulation is an educational strategy that can be harnessed further within engineering education. One area of application of simulation in engineering education is in work-integrated-learning (WIL) context.

Applying simulation within WIL context

Though not mandated yet, engineering degrees are expected to accommodate a WIL component. In a 2009 report submitted to the Australian Teaching and Learning Council (ALTC) it was found that not all students can access traditional WIL due to factors such as visa restrictions for International students, language, cultural background and disability (Patrick et al., 2008). Some of the key challenges of implementing WIL is to fulfil both the requirements of the university and the organisation, as well as controlling the outcome and process in traditional WIL to ensure that students get the most benefit (Patrick, et al., 2008). Despite reported benefit of WIL for industry organisations such as being able to access expert knowledge of the partnering university and advantages for recruitment (Li & Randhawa, 2009; Patrick et al., 2008), traditional WIL takes considerable investment of time and commitment from the industry partners. Organisations involved in WIL believed that the cost of mistakes that students can make while working in their organisation also needs to be considered (Patrick et al., 2008).

The benefits that simulation-based WIL can offer are the following: a) can be used to overcome opportunity limitation; b) requires less implementation time/risk of/to real industry, and c) can be tailored for specific learning opportunities. In addition, though within health professional education, the research of Watson et al. (2012) and Hayden et al. (2014) found no statistically significant differences were found between students engaged in traditional clinical placement and simulated clinical placement. This suggests that simulated WIL can be used to give students experiences that mimic real work placement.

Simulated WIL in engineering education context

The implementation of simulated WIL within engineering education context are exemplified in current literature (Jollands, 2015; Masethe & Masethe, 2013; Ponsa et al., 2010; Zou & Chan, 2016). Jollands (2015) developed a simulated WIL which comprised of a real project involving an industry partner. The project ran for 12 weeks and adding to the authenticity of the experience, students were mandated to adhere to special conditions including strict attendance and professional behaviour. Students were also required to attend workshops that covers professional and personal skills which include resume writing, interview skills, teamwork and communication. Like Jollands (2015), Masethe and Masethe (2013) implemented a project-based simulation. Students in their study designed and developed a mobile application through to putting it on the market. An industry partner was involved actively as mentors to the students. Students' learning was also supplemented by formal workshops and seminars.

Ponsa et al. (2010) utilised a project-based simulation using both computer-based and role-play modality. Their project was a joint-collaboration between two units within the Autonomous University of Barcelona (The School of Engineering and Sports Services Area) and a number of other institutions including the Technical University of Catalonia and 2 high schools. The Sports Services Area of the university acted as a client. Engineering students from the university were invited to submit CVs and their rationale for project participation. Students then took on professional roles and had regular meetings with the client as the project progressed. The simulated environment required students to design solutions for their client on a software-based application. In addition, students from the Technical University of Catalonia and the 2 high schools undertook specific roles such as software developers, designers and project managers to support the simulation activity.

In Hong Kong, also incorporating role play into a project-based simulation, 151 civil engineering students took on the roles of professional engineers, working in groups on a project involving a number of stakeholders (Zou & Chan, 2016). The project was borrowed from a real existing project. In the middle of the project, an emergency scenario was also introduced to students. This was done to replicate real industry conditions. Professional engineers were also at hand as advisors and facilitators. Unlike the simulated WIL developed by Jollands (2015) as well as Masethe and Masethe (2013), students' learning was not supplemented by seminars and workshops. Students were expected to be self-directed rather than guided by formal lectures.

Issues with project-based simulations: Adopting scenario-based simulation in engineering education

WIL simulations within engineering education often use a project within a team-based environment (Jollands, 2015; Masethe & Masethe, 2013; Ponsa et al., 2010; Zou & Chan, 2016). This mode of implementation may be driven by the nature of engineering work. However, as briefly mentioned by Zou and Chan (2016) such simulations made coordination challenging. In addition, since the value of simulation-based learning is the ability to design experiences in a controlled manner to achieve learning objectives (Fanning & Gaba, 2007), how much control can be applied within a project-based simulation is unclear given the larger scope and complexity.

The other issue of using project-based simulation is the prolonged involvement of the industry partner to add authenticity to the experience. Given that staffs from the involved organisation are often time-poor, this arrangement can be problematic from the perspective of the industry partner. However, involvement from the industry is vital as Jonassen, Strobel and Lee (2006), and Beder (1999) identified that problems faced by engineers in the real workplace differ significantly from those presented in a university setting. Balancing involvement and time required in a simulation-based learning activity can be challenging.

Another concern in implementing a project-based simulation is ensuring that learners are not overwhelmed by information and the tasks that they have to complete over the lengthened simulation duration. In Cognitive Load Theory, Sweller, Ayres and Kalyuga (2011) suggested that there is a limitation on how much learners can process information at one time. This has an impact on teaching and learning design. There is a need to consider issues of cognitive overload when carrying out simulations (Josephsen, 2015; Reedy, 2015).

In summary, it can be proposed that implementing a project-based simulation can be challenging in three areas: i) the issue of control and coordination of elements (including of human players) within the simulation to achieve learning objectives, ii) balancing industry's involvement and time required from them and iii) managing cognitive overload.

In contrast, within health professional education, team-based simulations are often scenario-based. That is, a specific event is played out with a healthcare team required to recognise and respond to the cues they are given in their effort to provide safe care. The use of simulated scenarios in engineering education context is achievable as exemplified by the work of Prince (2006) as well as Zou and Chan (2016). Prince (2006) used role-play and simulated scenarios to teach ethics, related to moral dilemmas to engineering students. The use of scenarios may also focus industry's involvement to the development of the scenarios, minimising industry partners' commitment during the actual simulation. Via scenarios, the teacher may be able to target narrower but more specific learning goals which may not overwhelm the students, thus considering aspects of cognitive overload.

The challenge of engaging students in reflection

Engaging students in reflection is a challenge in the design of any learning activities. Apart from Jollands (2015), in the previously discussed literature on simulated WIL, how students were engaged in the process reflection seemed to be unclear. Jollands (2015) recognised that the process of reflection is crucial for learning and implemented discussions together with the use of personal journals in her simulated WIL. However, in his study on the use of online reflective journal, Palmer (2004) found that students were only reflecting as necessary to complete their assignment and were unlikely to engage in the process when the assignment was over. This suggest that students may not be actively engaged in the process of reflection even if personal reflection is being enforced.

In addition, young engineers do not perceive the process of reflection as important (Adams, 2010; Belski & Belski, 2014; Harlim & Belski, 2010). Young engineers only tend to reflect if a mistake happens (Harlim & Belski, 2013a). While the use of simulation can provide a safe learning environment for students to make and learn from their mistakes (Ziv, Ben-David, & Ziv, 2005), the simulation implemented needs to facilitate opportunities for students to engage in meaningful personal reflection. This is supported by the research of Davidovitch, Parush and Shtub (2006). Industrial engineering students were asked to complete project management case studies on a computer-based simulator. The researchers then compared the performance of students in different groups, a) those who did not have any recorded history which they can use a way to gain feedback on their performance, b) those with automatic saving of recorded history and c) those who used student-led (manual) history recording. It was found those that had access to the history of their past performance outperformed those who did not have recorded history, during subsequent simulations. This shows that the simulation activity alone is not sufficient for effective learning. Mechanisms that facilitate reflection need to be considered when using simulation as an educational tool.

The Simulation Cycle - Learning from Health Professional Education

A systematic approach to simulation-based learning design experience can be utilised in simulation of events. The systematic approach, referred to the Simulation Cycle (The NHET-Sim Monash Team, 2012) considers simulation as a whole process and is made up of the following phases: i) preparation, ii) briefing, iii) simulation activity, iv) debriefing and feedback, v) reflecting and vi) evaluating. The Simulation Cycle as depicted in Figure 1, accommodates the processes that learners need to ensure effective learning can occur via simulation.

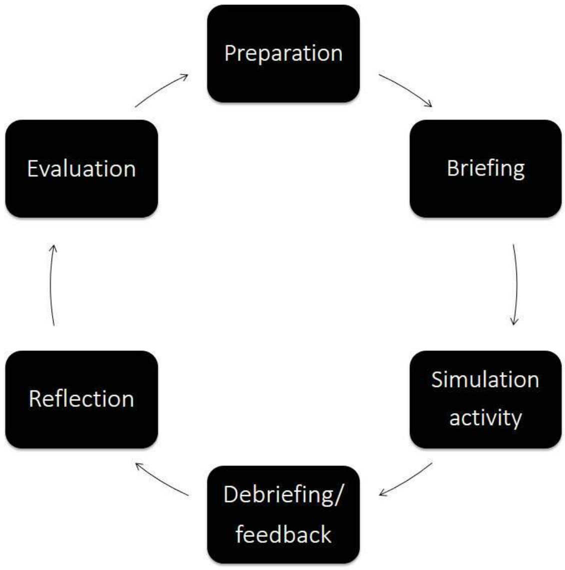

Figure 1: The Simulation Cycle, Source: Adapted from the NHET-Sim Program

The *preparation* phase refers to all the activities that take place before the simulation event starts, including the identification of learners' needs; setting learning objectives; designing the scenario, sourcing what is needed for the simulation such as rooms, props, human resources etc. The *briefing* phase is crucial to ensure that a valuable learning experience can be achieved (Gough, 2016). This phase helps to orient the learners prior to the simulation activity. The briefing would include explicit explanation of the simulation activity as well as the students' and facilitators' responsibilities. Reedy (2015) proposed that by preparing student mentally on what is going to happen during the simulated event can reduce cognitive overload. In addition, students can be assured that the simulated event is a safe place to make mistakes during in this phase.

During the *simulation activity,* the learner(s) participate actively in the simulation. To ensure that students are aware that the simulation has begun and thus, they are engaging in a safe place to make mistakes, it is important to indicate a clear start to the simulation. Within a project-based simulation, it is challenging to implement this as students enter and exit the simulation without a clear indication, contributing to the challenge of control and coordination of the learning environment.

The process of *debriefing and feedback* is used a pre-cursor to self-reflection. Within health professional education, this phase is considered to be the most important part of simulation-based education. It is suggested that this is the process that leads to effective learning (Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2005; Motola, Devine, Sullivan, & Issenberg, 2013; Shinnick, Woo, Horwich, & Steadman, 2011). Going beyond discussions which are often implemented within simulated WIL in engineering education, formalised feedback and debriefing sessions may be used to promote reflection. Evidence of the effectiveness of debriefing has been reported (Benbow, Harrison, Dornan, & O'Neill, 1998; Cheng et al., 2014; Decker et al., 2013; Fanning & Gaba, 2007; Issenberg et al., 2005; Motola et al., 2013; Rudolph, Simon, Dufresne, & Raemer, 2006). In addition, the process of debriefing may also be more representative of what takes places within the engineering profession, adding to authenticity to the simulated WIL. Within the *reflecting* phase in the Simulation Cycle, learners are encouraged to make sense of the simulation in the light of their own experiences, individually. By engaging students in the process of debriefing prior to personal reflection (either via personal journal or other means), it is hoped the discussion during the debriefing session would activate their own locus of control to engage in meaningful reflection.

Finally, the *evaluation* phase refers to assessment of the success and limitations of the simulated session in meeting its goals. This phase is about ensuring continuous improvement in the use of the educational strategy. It is proposed that the adoption of a scenario-based simulation accommodate the use of the Simulation Cycle, which may be used to overcome the issues that have been identified in implementing simulated project-based WIL. It is also believed that the Simulation Cycle may also address the challenge of encouraging meaningful reflection in engineering students.

Conclusion - Where to from here?

It is suggested that the use of simulation can be further harnessed within engineering education, particularly in the development of simulated WIL. It is proposed the practices within health professional education can improve the utilisation of simulation as an educational strategy. These include the use of scenario-based simulations rather than project-based, and the use of the Simulation Cycle.

The authors of this paper are working on developing 2-3 simulated scenarios-based WIL with the involvement of industry partners that focus on aspects of engineering problem solving, related to problem analysis skills. The focus of development is such as it is well identified that problem solving ability is an important skill for professional engineers (Beder, 1999; Engineers Australia, 2013; McCarthy, 2009). In addition, research found that problem finding or the skills to diagnose problems properly is vital for problem solving performance (Belski, Adunka, & Mayer, 2016; Harlim & Belski, 2013b).

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Modelling Innovation Process in Multidisciplinary Course in New Product Development and Inventive Problem Solving

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SESSION S2: Educating the Edisons of the 21st Century

CONTEXT This paper addresses the needs of the universities regarding qualification of students as future R&D specialists in efficient techniques for successfully running innovation process. In comparison with engineers, students often demonstrate lower motivation in learning systematic inventive techniques, for example, TRIZ methodology, and prefer random brainstorming for idea generation. The quality of obtained solutions also depends on the level of completeness of the problem analysis, which is more complex and time-consuming in the case of interdisciplinary systems. This paper briefly describes a one-semester-course of 60 hours in new product development with the Advanced Innovation Design Approach and TRIZ methodology, in which a typical industrial innovation process for one selected interdisciplinary mechatronic product is modelled.

PURPOSE The article investigates the opportunities and advantages of a novel educational approach, analyses the learning experience, identifies the factors that impact the innovation and problem-solving performance of students, and underlines the main difficulties faced by the students in the course, especially in the case of interdisciplinary problems.

APPROACH The mechanical engineering students are working in a course as R&D department. They formulate a comprehensive innovation strategy and define the measurable goals for innovation tasks first. This is followed by idea generation and the creation, evaluation, and comparison of new product concepts for further implementation.

RESULTS Fast utilisation of learned innovation skills in practice encourages the ability of self-directed learning and strengthens the motivation. As a full-scale new product development project is too time-consuming for one semester, the idea generation and problem-solving phase should be limited to one or two inventive tasks for each team of students. Examples demonstrate innovation strategies proposed by the students during the course.

CONCLUSIONS The presented results, including recommendations for selected tools and educational methods, can help universities to establish the education in comprehensive new product development and systematic inventive problem solving or to improve its performance.

KEYWORDS new product development; inventive problem solving; innovation process; TRIZ methodology

Introduction

An ongoing qualification of R&D specialists and engineers in techniques that ensure a successful running of an innovation process has become very important for the competitiveness of enterprises. Over the last two decades, industrial companies, e.g. Samsung (Kim et al., 2005) or Siemens (Adunka, 2007), as well as numerous universities and educational institutions in Australia (Belski, 2007), Czech Republic (Jirman and Busov, 2010), Finland (Ryynänen and Riitahuhta, 2010), France (Oget and Sonntag, 2002), Italy (Cascini et al., 2008), Japan (Nakagawa, 2007), the Netherlands (Witts et al., 2010) and the USA (Domb et al., 2010) have gathered considerable positive experience in different education approaches in the systematic innovation and the theory of inventive problem solving TRIZ. For example, Valentine, Belski, and Hamilton (2016) have found that explaining how to apply even simple creative TRIZ inventive techniques such as MATCEMIB operator to engineering students results in a significant increase in the students' long-term creativity. At the same time, Harlim (2012) demonstrates that the enhancement of the problem-solving skills of university students and experienced engineers requires different approaches, which have to be investigated more thoroughly. Livotov (2015) underlines that students have lower motivation in learning TRIZ methodology than engineers, especially regarding such core TRIZ competences as fast and systematic inventive problem-solving.

TRIZ and Advanced Innovation Design Approach

The theory of inventive problem-solving (TRIZ), developed by Altshuller and his co-workers (Altshuller, 1984), is today considered as one of the most organized and comprehensive methodologies for invention knowledge and creative thinking (Cavalucci et al., 2015). This statement can be confirmed by the analysis of the most-cited scientific publications on innovative design performed by Chechurin and Borgianni (2016). In addition to its unique ideation techniques, TRIZ includes different problem definition methods, such as Substance-Field Analysis and the System Operator (Altshuller, 1984), Function Analysis (VDI Standard, 2016), Cause-Effect Chain Analysis (Dobrusskin, 2016), Root-Conflict Analysis RCA+ (Souchkov, 2005), and others. Harlim and Belski (2015) discuss the implications of these and other TRIZ tools for problem definition on the design of educational programs. Spreafico and Russo (2016) analyse TRIZ tools used in more than 200 industrial case studies and underline that the classical easy-to-use problem definition tools are at the bottom of the list with the frequency-of-mention of 16% for TRIZ Function Analysis and 13% for the System Operator.

The early stage of the customer-centered innovation process has been one of the focal points of the innovation research over the last decade (Kotsemir & Meissner, 2013). The challenges of the front-end innovation have defined the new development directions of the TRIZ methodology (Litvin, 2011; Abramov 2014). In accordance to Cooper and Kleinschmidt (2007), a high-quality innovation process, including its comprehensive and fault-free execution, belongs to the critical success factors in new product development. In the early stage of the process, companies have to discover the latent needs of customers or opportunities for customer satisfaction of which the customers are unaware (Narver et al., 2004). A number of researchers have reported on various new methods to uncover customer needs in addition to the classical voice-of-the-customer approaches (Christiano et al., 2000). Analysis of the customer working process (Bettencourt and Ulwick, 2008), analysis of market and technological trends known in TRIZ, and evolutionary analysis of customer needs (Petrov, 2005) are some of these new methods.

The consolidation of a comprehensive front-end innovation process with advanced innovation methods and modern TRIZ tools has been proposed and explored in the research project "Innovation Process 4.0" run at the Offenburg University in co-operation with the industrial companies in 2015-2017. This research work has resulted in the definition of the new Advanced Innovation Design Approach (AIDA). The AIDA innovation process with self-configuration, self-optimization, self-diagnostics, and intelligent information processing and communication comprises the following typical phases with feedback loops and simultaneous auxiliary or follow-up processes: uncovering of solution-neutral customer needs, technology, and market trends, identification of the needs and problems with high market potential and formulation of the innovation tasks and strategy, systematic idea generation and problem solving, evaluation and enhancement of solution ideas, creation of innovation concepts based on solution ideas, evaluation of the innovation concepts, and implementation, validation, and market launch of chosen innovation concepts.

The new development in the field of systematic innovation discussed above has been implemented in a novel course in new product development and inventive problem solving for mechanical engineering students. The one-semester course has a total workload of about 120 hours, including 4 hours a week of lectures and practical work under the guidance of a professor. The course is modelling a front-end innovation process and combining a product development project (about 50% of the complete workload) with the auxiliary education in creativity and problem-solving techniques of the TRIZ methodology. The engineering students are working in a course as R&D department. They formulate a comprehensive innovation strategy and define the measurable goals for innovation tasks first. This is followed by the idea generation and the creation, evaluation, and comparison of new product concepts for further implementation.

Educating Front End Innovation Process

The innovation process run in the course includes two initial phases: definition of customer-driven innovation strategy, followed by the innovation concept development, as shown in the Table 1. The engineering students are working in a course in the small teams of 4...6 persons.

Table 1: Structure of the innovation project in the course

Step No.	Phase 1 Innovation strategy formulation	Step. No.	Phase 2 Innovation concept development
1	Initial situation analysis	6	Systematic idea generation with TRIZ
2	Function analysis of the product and customer process mapping	7	Combining ideas to the solution concepts
3	Capturing solution-neutral customer needs (benefits)	8	Evaluation of innovative solution concepts
4	Evaluation of market potential of benefits as innovation tasks	9	Optimisation of the solution concepts
5	Selection of innovation tasks for the innovation strategy	10	Choosing the optimal innovation concept for the implementation

The method for customer-driven innovation strategy formulation and planning of R&D activities starts with the analysis of situation on the market and the recent patent information, followed by a description of all the essential components of the actual technical systems, their useful functions, and undesired or negative properties (see Table 1, Steps 1 and 2). A thorough analysis of the customer working process, the market, and current technological trends by the web monitoring are additionally performed by the students to obtain a complete picture of customer needs. A complete list of all thinkable innovation tasks is formulated in Step 3 on the basis of the identified market and customer requirements and a detailed function analysis. These tasks are understood as customer benefits, which are independent of known technologies or solutions and correspond to the further improvement of positive functions or the elimination of negative properties in the analysed products.

After the capturing of customer benefits is completed, the importance of each benefit and its current performance is evaluated from a customer's point of view in Step 4 using a scale from 0% to 100% (100% - very high level of importance or performance, 80% - high, 60% - middle, 40% - low, 20% - very low importance or performance). The task with the higher importance and lower performance can be selected later for the ideation and new concept development in Phase 2.

In one of the courses, a group of 29 students in their 8th and 9th study semesters of the Master of Mechanical Engineering degree program at the Offenburg University was involved in the development of a new high-quality motor-driven chainsaw for forest, park, and garden applications. The estimation of the market potential of innovation tasks using an example of a petrol-driven chainsaw is illustrated in Table 2. The top 5 of the 50 benefits of using a petrol-driven chainsaw with the highest market potential were selected by the students as the innovation tasks for the new chainsaw development.

Table 2: Top 5 of the 50 benefits of using a petrol-driven chainsaw with the highest innovation and market potential estimated by the students

No	User benefit (innovation task)	Importance	Performance
1	26. Indicate trees under tension	77%	30%
2	1. Low weight of chainsaw	93%	52%
3	44. Low noise emission	75%	40%
4	46. Easy and quick cleaning	85%	54%
5	28. Effortless delimbing	88%	57%

Phase 2 (Innovation concept development) of the innovation process is based on a comprehensive initial problem analysis performed during Phase 1. All innovation tasks selected in Step 5 of Phase 1 are understood in Step 6 as partial problems $P_1 \dots P_n$, (see Figure 1). In this step, the strongest TRIZ inventive principles replace random brainstorming, increasing the quality and quantity of ideas within a short period of time. For each partial problem, several ideas must be generated, and no relevant idea should be overseen. After the ideation process, the proposed ideas should be combined with the solution concepts (Step 7). A robust solution concept delivers solutions for all partial problems. The solution concepts often have their secondary side-effects, like costs, risks, or R&D expenditures, which must be identified in Step 8 and limited through concept optimization in Step 9. The synthesis of a concept in Step 9 is completed if suitable complementary solutions have been chosen for each problem. Several competitive concepts can be created and compared at this stage with different objectives, such as the maximum growth of total product performance and optimisation of the costs, risks, or R&D expenditures. The process ends with a well-founded selection of preferred innovation concept in Step 10.

Educating Auxiliary Inventive Skills

The efficiency of the students' work in the second phase of the innovation process strongly depends on their engineering creativity and problem analysis and inventive problem-solving skills using the TRIZ methodology. Such skills are obtained during the course through seven supporting training units presented in Table 3. The integration of these auxiliary training units in the first part of the course encourages students to immediately apply their newly-acquired skills in the new concept development.

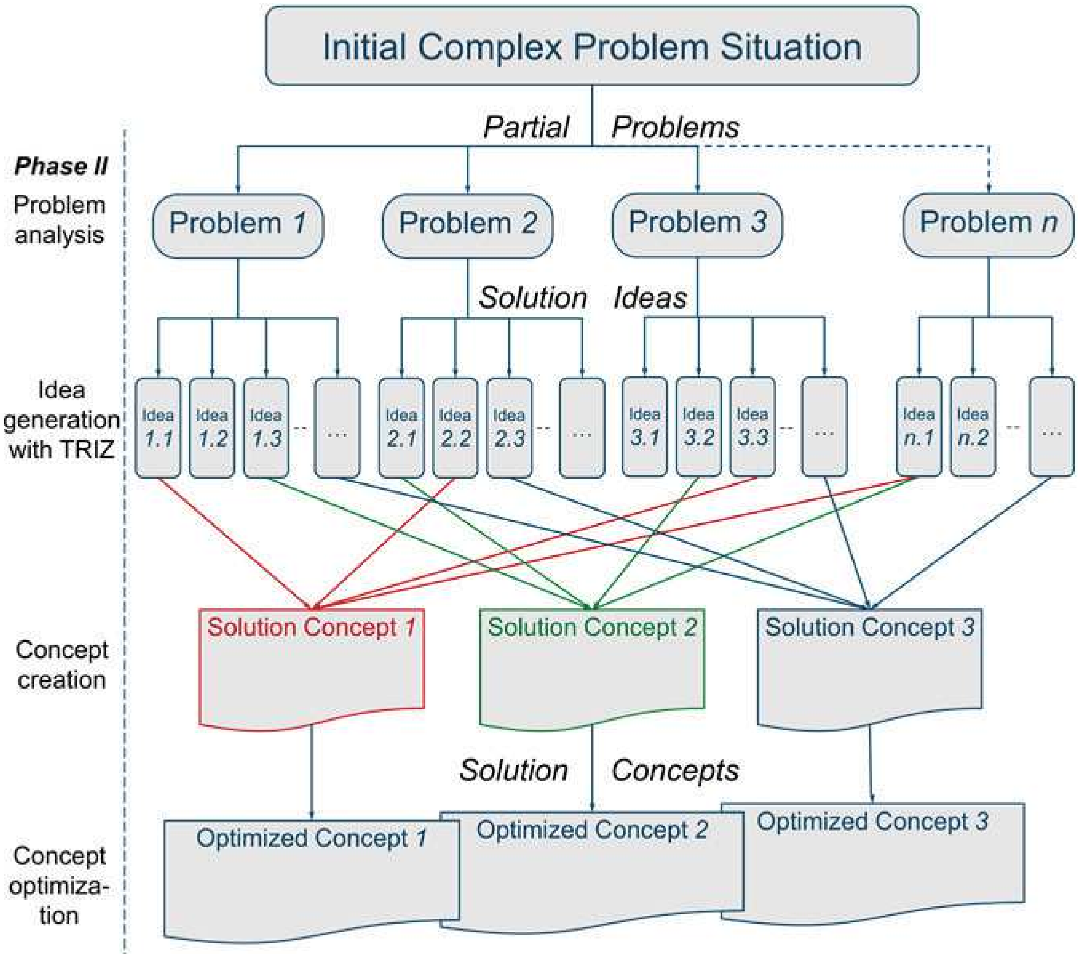

Figure 1: Phase 2 of the project run during the course - Innovation concept development

Table 3: Auxiliary training units in the inventive problem solving

No.	Title of training unit	Number of exercises
1	Enhancement of personal creativity, resources- and contradiction-oriented thinking, System Operator	4…5
2	Elimination of undesired properties and harmful effects with cause-effect analysis and 40 TRIZ inventive principles	2…3
3	Solving engineering contradictions with 40 TRIZ principles	2…3
4	Cost reduction and trimming in technical systems	1…2
5	Inventive algorithm ARIZ (short form), identification and resolving of physical contradictions with separation principles	2…3
6	Anticipatory failure identification: prediction of potential failure scenarios for new products or processes	2…3
7	Prediction of future technical product features with evolution patterns of technical systems	1…2

Challenges of Mechatronic Systems

When applying TRIZ for inventive problem solving, the quality of obtained solutions depends on the ability of students to understand problem situation completely and to identify the core engineering contradiction(s) of the technical system. The complexity of these tasks increases when dealing with interdisciplinary mechatronic problems. The observations made in the course show that mechanical engineering students primarily focus on the monodisciplinary mechanical problems and can oversee multidisciplinary interactions. In order to overcome such difficulties, the pre-defined set of system components for the function analysis can be recommended to the students. It reflects the typical structure of a mechatronic product: the basic mechanical structure, actuators, energy supply, sensors, control unit, software, information and data processor, mechanical, electrical and human interfaces, etc.

Table 4: Illustration of the Cause-Effect-Matrix (CEM) for interdisciplinary systems

Fields of the Substance-Field Analysis:	1. Mechanical	2. Acoustic	3. Thermal	4. Chemical	5. Electrical	6. Magnetic	7. Intermolecular	8. Information, data processing	9. Biological, Human
Negative **Consequences**									
...									
Negative **Effect** (level 1)									
Causes of negative effect									

If the identification of contradictions or cause-effect chains in mechatronic systems appears to be difficult, an easy-to-use method called Cause-Effect-Matrix (CEM) proposed by the author at the Offenburg University can be suggested. The CEM combines a simple TRIZ ideation technique MATCEMIB known in the Substance-Field Analysis (Valentine, Belski and Hamilton, 2016) with the cause-effect-consequence observations in a problem situation. Table 4 explains the fast CEM method, which helps to identify interdisciplinary root-cause chains and can support students during the whole problem formulation process. Supplementary to the eight MATCEMIB fields (Mechanical, Acoustic, Thermal, Chemical, Electrical, Magnetic, Intermolecular, and Biological fields), two additional fields, namely the information field and the influence of human operator, are included in the positions 8 and 9 of the matrix. These two additional fields help mechanical engineering students to take into consideration the aspects of information and data processing in the control system and the issues related to the Human-Machine-Interface.

For example, starting with mechanical cause of a negative effect at the bottom level (e.g. bearing friction, see Table 4), a student can easily see and document the negative thermal effect (overheating) that may further lead to a chemical problem (e.g. degradation of grease properties). Another example shown with the dotted line starts with the acoustic consequences of a harmful effect (e.g. noise) caused by the electrical field (e.g. electrical drive) due to the human operator error. Different cause-effect-consequence chains can be checked rapidly top-down or vice versa in this way. Nevertheless, the fast and at the same time complete and error-free problem situation analysis remains one of the challenging factors in the educational process as the results of student work demonstrate a large variation in the interpretation of the same problem.

Concluding Remarks and Outcomes of the Course

The proposed course simulates the challenges of the front-end innovation project. The immediate utilization of learned innovation skills in practice motivates students to learn creativity and inventive methods dynamically and proactively. As a full-scale new product development project is too time-consuming for one semester, the idea generation and problem-solving phase should be limited to one or two inventive tasks for each team of students.

The course offered since 2015 at the Offenburg University was highly appreciated by the majority of participants, who were able to propose or to decisively codetermine the areas of their innovation projects for several new products, such as lawnmower, chainsaw, core drilling machine, dishwasher, robot vacuum cleaner, automated car wash, electric power tools, etc. The students of the course demonstrated competent application of the learned skills and could systematically select top five innovation tasks from the identified 30 to 60 solution-neutral customer needs. The application of the TRIZ inventive principles enabled an efficient development of patentable ideas and solution concepts during the project.

The presented analysis and experience, including recommendations for selected tools and educational methods, can help universities to establish the education in comprehensive new product development and systematic inventive problem solving or to improve its performance.

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The Allocation of Time Spent in Different Stages of Problem Solving: Problem finding and the development of engineering expertise

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SESSION S2: Educating the Edisons of the 21st Century

CONTEXT Four major steps of problem solving include understanding the problem, planning the solution/s, implementation and evaluation. Despite a significant body of research on engineering problem solving, it is unclear how the problem solving steps occur in practice and whether there are any differences in the approaches of engineers with varying industry experience.

PURPOSE The research questions investigated were: a) Based on the first 3 stages of problem solving process: i) Understanding the problem, ii) Planning, and iii) Implementation, what proportion of time is devoted by engineering practitioners to each step? and b) Does the time devoted to the different stages of problem solving change over the years in profession?

APPROACH A survey method was undertaken and 215 engineers with varied industry experiences as well as fields were involved in the study. The responses were then categorised based on different levels of industry experience from novice to experts. The data were analysed statistically with SPSS software.

RESULTS It was found that differences exist between the responses of the different groups of engineers. It was observed that there is a link between industry experience and the time spent at different stages of problem solving, especially in Stage 1 (Understanding the problem).

CONCLUSIONS A number of key findings are presented in this study. It was found that industry exposure is crucial for the acquisition of skills that are important for proper problem understanding. The study also provides the evidence that around 10 years of industry experience really formed engineering expertise. These findings have implication to the future development of educational strategies, including in the choices of the type of heuristics that may assist young engineers in developing their problem analysis skills more effectively.

KEYWORDS Engineering problem solving, development of expertise, problem finding, problem solving models

Problem solving models

One of the key defining models of problem solving was developed by Polya (1945) in his work on mathematics problem solving. Polya (1945) advocated that mathematical problem solving consists of four distinct steps: understanding the problem, planning the solution, implementation of the solution and finally, looking back. Carlson and Bloom (2005) evaluated problem solving behaviours of 12 mathematicians as they attempted to solve four mathematics problems. They discovered that the four-step problem solving process advocated by Polya is cyclic and proposed a more accurate framework of mathematical problem solving. In observing their expert subjects, Carlson and Bloom (2005) found that they engage in trial and error, oscillating between the planning and verification stages, until the solution is established. Specific to engineering, Belski (2002) proposed a seven-step process of engineering problem solving that was based on Systems Thinking. He recommended numerous heuristics that can be used at each step of the seven-steps process. Belski (2002) also believed that the problem solving steps are inter-connected.

Despite the differences in the models, all of them can be fitted into four key steps: (Stage 1) understanding the problem, (Stage 2) planning, (Stage 3) implementation and (Stage 4) evaluation. A summary of the three problem solving models discussed above is presented in Table 1.

Table 1: Problem solving models

	(Polya, 1945)	(Carlson & Bloom, 2005)	(Belski, 2002)
Stage 1: Understanding the problem	1) Understanding the problem	1) Orienting: sense making, organising, constructing	1) Situation analysis 2) Revealing the system's stage of development
Stage 2: Planning	2) Developing a plan	2) Planning: conjecturing, imagining, evaluating	3) Identifying an ideal solution 4) Idea generation
Stage 3: Implementation	3) Carrying out the plan	3) Executing: computing, constructing	5) Failure prevention 6) Adjusting the super-system and sub-systems in accordance with the solution found
Stage 4: Evaluation	4) Looking back	4) Checking: verifying, decision making*	7) Reflection on the solution and the process of the solution

* If solution is inaccurate, then return to stage 2.

The importance of understanding the problem

Recent studies found that Stage 1, understanding the problem or problem finding, is considered to be the most important stage in the problem solving process (Belski, Adunka, & Mayer, 2016; Harlim & Belski, 2013b). Newell and Simon (1972) also suggested that "when a problem is first presented, it must be recognised and understood" (p. 809).

Newell and Simon (1972) believed that problem solving relies on pattern recognition. Their theory relied heavily on the concept of the accumulation of knowledge and developing expertise. Experts resolve problems well as they have well-developed schemata (Gick, 1986; Kalyuga, Ayres, Chandler, & Sweller, 2003; Kalyuga, Renkl, & Paas, 2010). As experts are considered to be better problem solvers, there has been a number of investigations focusing on expert problem solving (Atman, Chimka, Bursic, & Nachtmann, 1999; Belski et al., 2016; Bilalic, McLeod, & Gobet, 2009; Carlson & Bloom, 2005; Chi, Glaser, & Rees, 1982; Gick, 1986; Gobet & Simon, 1996). The outcomes of such research can be used in educational settings to develop strategies that will facilitate the advancement of problem solving skills of novice engineers.

Reflection differences

The role of evaluation (reflection) in engineering problem solving is not explored in this paper. The process of reflection is utilised and perceived differently by novice and expert engineers (Harlim & Belski, 2013a). In addition, novices have the misconception that reflection is not necessary (Adams, 2010; Harlim & Belski, 2010). Therefore, this paper will only focus on the first 3 stages of problem solving: understanding the problem, planning and implementation.

Research questions considered

Two research questions are explored:

1) Based on the first 3 stages of problem solving process: i) Understanding the problem, ii) Planning, and iii) Implementation, what proportion of time is devoted by engineering practitioners to each step?
2) Does the time devoted to the different stages of problem solving change over the years in profession?

Methodology

A survey method was undertaken to evaluate the research questions and the data were analysed statistically with SPSS software. The survey was part of a larger study spanning the years of 2009 to 2011 investigating the factors that impact on engineering problem solving performance. Participants were asked to reflect on the distribution of time during their problem solving practice by responding to the following question:

> *Think back of ONE engineering problem that you had resolved recently. Please allocate how much time you spent on each problem solving stage stated below (in percentages out of a total 100, e.g., 30, 50, 20).*

In the questionnaire, it was specified that the problem solving stages include:

- Stage 1: Understanding the problem (diagnosing the problem)
- Stage 2: Planning the solution/s (identifying the possible solution/s, and planning the implementation
- Stage 3: Implementation of the solution/s

A total of 215 engineers responded to the question, including 167 male and 48 female engineers. Within those who took the survey, 144 were engineering students, 56 were professionals and 15 were academics. The engineers who were involved in the study came from a variety of engineering background including Aerospace, Automotive, Mechanical, Biomedical, Chemical, Civil, Computer and Network, Electrical, Electronic and Communication, Environmental, Industrial as well as Mechatronics.

The data were then segmented into different classification of expertise. It was observed that young engineers in the research fitted in two categories: Novice Class 1 (N1) and Novice Class 2 (N2). Professionals with more than 10 years of industry experience were classified as experts (E) using the work of Chase and Simon (1973) as well as Prietula and Simon (1989) as guides. They proposed that experts are those who have more than 10 years of experience in a specific field (Chase & Simon, 1973; Prietula & Simon, 1989). Those in between the novice and expert groups were classified as mid-level engineers (M). Table 2 summarises the division of the survey participants into categories.

Table 2: Summary of categories based on level of expertise

Classification	Years of full-time work in engineering
Novice Class 1 (N1)	0 years (Students and recent graduates with no industry experience in the engineering field)
Novice Class 2 (N2)	equal to or less than 5 years
Mid-level (M)	6-10 years
Experts (E)	over 10 years

In the final analysis, responses that did not yield 100% when each of the three allocation of problem solving stages were added up were treated as outliers and removed. An example of this is when an engineer indicated that he or she had allocated 60% to Stage 1, another 60% to Stage 2 and 50% to Stage 3. A total of 197 responses were included in the final analysis.

Findings

Table 3 and Figure 1 present the findings on how the engineers surveyed spent their time within the three problem solving stages.

Table 3: Time allocated by engineers to different stages of the problem solving process

Classification	Number of responses included in the analysis	Stage 1 (%)	Stage 2 (%)	Stage 3 (%)
N1	85	M=28 SD=14	M=38 SD=17	M=34 SD=20
N2	63	M=33 SD=14	M=36 SD=15	M=31 SD=16
M	22	M=45 SD=16	M=31 SD=11	M=25 SD=14
E	27	M=31 SD=18	M=34 SD=13	M=35 SD=19
TOTAL	197			

Figure 1: The proportion of time spent by engineers with different industry experience in the three stages of problem solving process.

Engineers with no industry experience (N1) spent the least time of the four groups in Stage 1 compared to the time spent on the other stages of problem solving (28% on Stage 1, 38% on

Stage 2 and 34% on Stage 3). The trend changed as the engineers gained industry experience. Although most of the time was still spent on the planning stage (36%), those with five years or less of industry experience (N2) reported spending more time on understanding the problem (33%) than on implementation (31%) in comparison to N1.

As the engineers gained 6 to 10 years industry experience (M), a clear reversal was observed. Most of the time was spent on Stage 1 with an average of 45%. 31% of time was spent on Stage 2 and 25% on Stage 3, indicating that in this group there is an obvious focus on problem identification. The engineers with industry experience of more than 10 years (E) reported spending less time on Stage 1 (31%) than on the other stages (34% on stage 2 and 35% on stage 3). The trend was similar to that of the N1 group, engineers with no industry experience.

Before investigating whether statistical significance existed in the responses of these groups, the Kolmogorov-Smirnov Test was carried out to determine the most suitable statistical test for the data obtained. Due to the violation of parametric assumption of normal distribution in the data, the non-parametric test, the Kruskal-Wallis Test, was used. Statistical significance was found between the groups only in their responses on how much time was spent in Stage 1, understanding the problem ($p=0.000$).

To determine where the statistical significance occurred in the data, the responses of each individual category for Stage 1 was tested in pairs using the Mann-Whitney U-Test. Time devoted to Stage 1 by the practitioners from the N1 and N2 groups did not differ much from that spent by the engineers from the E group. The difference in time devoted to Stage 1 between all other pairwise group combinations was statistically significant. The outcomes of the Mann-Whitney U-Test are presented in Table 4.

Table 4: Statistical analysis on group comparisons of time spent on understanding the problem

Comparison group	P-value
N1 – N2	0.020*
N1 – M	0.000*
N1 - E	0.445
N2 – M	0.005*
N2 - E	0.378
M - E	0.005*

*Statistical significance is observed ($p<0.05$ or $p<0.01$).

Discussion

The comparison of responses from the engineers with different industry experiences reveal an interesting pattern. The results from the two novice groups indicated that they are focused on the planning phase (Stage 2). The data from the mid-level group indicated a clear focus on understanding of the problem (Stage 1). Similar to the novice groups, the expert group reported spending more time in the planning stage.

Statistical significance was only observed within the data of Stage 1, understanding the problem, when the four categories of practical experience were compared. This suggests that the gain of professional experience mainly influences the way engineers conduct the problem diagnosis stage. In other words, statistically significant changes in time devoted to problem analysis over the years of professional practice suggest that acquiring advanced skills in problem analysis is paramount for gaining engineering expertise. This conclusion supports the idea that Stage 1 is an important aspect of problem solving performance (Belski et al., 2016; Harlim & Belski, 2013b). Therefore, this highlights that the key area of learning that should be focused on during engineering problem solving should be the problem analysis stage.

Statistical significance was also found when the responses of N1, novices with no industry experience, were compared to those of N2 (novices with 5 years or less of industry experience). This finding indicates that industry experience exposure leads to the realisation on the importance of problem identification for effective problem solving. This is also supported by the responses of the engineers in the mid-level group (M), those with 6-10 years of industry experience. The data reveals that industry experience between 6-10 years is the crucial period in the development of problem solving skills for engineers as a distinct focus on Stage 1 was observed. When the responses of the engineers in the M category were compared to all the other groups (N1, N2 and E), statistical significance was also found. The implication is that perhaps to discover how novices can be better problem solvers, there is a need to investigate what happens during these formative years.

The results of the survey indicate that as expertise is reached, the amount of time spent in Stage 1 decreases compared to those in the N2 and M groups. Literature in cognitive science has identified that experts are able to by-pass the search strategy when resolving problems due to their well-developed schemata which enable them to solve problems better and at a much quicker rate (Kalyuga et al., 2003; Kalyuga et al., 2010). Therefore, this finding is not surprising.

However, the data shows that both N1 and E groups spent the least amount of time in understanding the problem phase. It can be posited that these novices are behaving like experts when it comes to how they are spending their time in the different stages of problem solving. Much of problem solving studies have been conducted by the observation on how experts resolve problems. The outcomes of these studies were used to suggest how novices can learn to resolve problems from the strategies of their expert counterparts. This gives the assumption that when a novice behaves like an expert when solving a problem, he or she has truly become a good problem solver.

Although novices in this study devoted similar amount of time to Stage 1 as experts, they were unlikely to reach the problem comprehension of experts. As identified by Newell and Simon (1972), problem solving requires pattern recognition and the experts use of knowledge, stored in the long-term memory differs in experts and novices. Experts are better problem solvers due to the schemata they have in their long-term memory (Belski & Belski, 2008; Chi et al., 1982; Gick, 1986; Newell & Simon, 1972). When faced with situations to resolve, experts use these well-developed schemas to recognise the problems. Novices, on the other hand, do not possess knowledge schemas and need longer time to comprehend problems.

However, as exemplified in the data, novices emulate experts and do not devote adequate time to problem analysis. This study provides compelling evidence that this misconception by novices needs to be corrected. This may be addressed by teaching novice engineers more heuristics that focus on Stage 1 of the problem solving process. Some tools of the Theory of Inventive Problem Solving (TRIZ) can help novices to acquire the skills important for problem understanding (Harlim & Belski, 2015). Such heuristics includes the Size Time Cost Operator, the Notion of the Ideal Ultimate Result, the heuristic of Resources and the heuristic of Situation Analysis (Edisons21 Fellowship Team, 2016). In addition, strategies that expose them to industry conditions and situations can be considered to bring about the awareness of the need in spending more time in Stage 1.

In their research, Carlson and Bloom (2005) considered PhD candidates as experts in mathematical problem solving. Atman et al. (1999) compared the performance of senior versus first year students to gain insights on problem solving performance of experts. The difference between the responses of the engineers in the different categories, N1, N2, M and E strongly supports research findings that suggest that to achieve expertise, one needs 10 years or more of practical experience (Chase & Simon, 1973; Prietula & Simon, 1989). The results from this study show that a more stringent interpretation of expertise needs to be considered when designing studies on problem solving performance of engineering experts.

The implication is that there is a need to understand problem solving strategies of experts from the perspective of ‘why’ they resolve problems the way they do, rather than the mere ‘how’ or ‘what’.

Conclusion

A number of key findings are presented in this study. It was found that professional practice is crucial for gaining the skills that are necessary for proper understanding of the problem. The data also revealed that this is the key stage that engineering educators should be focusing on in order to develop the problem solving skills of young engineers adequately. Novice engineers that participated in the research, especially those with no industry experience did not spend sufficient time understanding a problem, as they lack the awareness and have a misconception on how experts resolve problems.

The study also provides the evidence that around 10 years of industry experience really formed engineering expertise. The implication is that when designing studies on how experts resolve problems, a more stringent interpretation of expertise should be considered. The results also revealed that experience gained between 6-10 years in the industry may be the formative years in bringing about the realisation that understanding the problem is imperative for effective problem solving.

These findings have implication to the future development of educational strategies, including in the choices of the type of heuristics that may assist young engineers to develop their problem analysis skills more effectively.

The limitation of this study is that the data were collected retrospectively based on the engineers’ perception on how much time was spent in each stage. Future research can investigate the research questions via proper observation or data collection during actual problem solving, using a non-self-reporting methodology. Future research can also investigate in depth how engineers with 6-10 years industry experience resolve engineering problems in practice. This will help to understand what happens during these years and may provide more insights on how novices can improve their problem solving skills.

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Developing three-dimensional engineers through project-based learning

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CONTEXT
The issue addressed is the need to develop engineering students' independent learning and their understanding of the range of professional engineering activities within the context of a large introductory engineering subject in a revised academic calendar with reduced teaching weeks. Thus a project was created to re-design the subject to take a structured approach to flipped and blended content delivery. This has provided a scaffolded and supportive environment to introduce students to collaborative project-based and independent learning.

PURPOSE
The project aims to create a coherent teaching and learning narrative to develop student engineering identities within an authentic student project which gives them insights into the nature of engineering work. This is done in a subject with strong tutor support to scaffold students" learning experiences.

APPROACH
The project uses transition pedagogies to scaffold blended and flipped learning experiences, and to make explicit the need to develop students' engineering identities. Active and interactive learning opportunities enhance students' agency to become independent learners. Data have been collected from students and tutors to measure the impact of the changes in learning and teaching practices. Student data are being analysed through the lens of developing professional identity. The effectiveness of the student learning activities are being evaluated using tutor feedback and assessment results.

RESULTS
Results indicate that due to the subject redesign, students have a stronger sense of the nature of engineering work. Furthermore, teaching and learning activities that focus on project-based learning have developed students' emergent professional identity and professional capabilities. In addition, the standardisation of teaching and learning experiences across tutorial classes have led to greater consistency in content delivery and learning outcomes.

CONCLUSIONS
It is critical to introduce students to project-based learning using a structured and scaffolded approach. This foregrounds the collaborative and three-dimensional nature of engineering work and highlights the complexities of developing professional capabilities and identities. Students develop these understandings at different rates; as is evidenced in both the student and the tutor comments thus flipped learning activities can provide opportunities for students to maximise classroom and peer-to-peer learning. Even with the structured activities, not all students embrace the need to develop professional skills as part of learning to become an engineer.

Key words: engineering identity; project-based learning; flipped learning

Introduction

Background:

The expectation that university students will unproblematically develop as independent learners is often not scrutinised by university administrators and academic staff, despite extensive research in adult learning (e.g. Biggs & Tang 2007; Bock, 1999; King & Kitchener 1994; Perry 1981) which demonstrates that intellectual capacity for judgement is not fully developed until people are in their mid to late 20s. In addition, students attending Australian universities are from highly diverse backgrounds, with a wide range of prior learning experiences. To add to the mix, developments in technology "have continued to alter the modes of student participation, the structures of course delivery, and relationships between students and teachers" (Baik, Naylor & Arkoudis 2015, p.1). Gardner's research in this area has demonstrated that "students who perform poorly in flipped learning environments typically do not demonstrate the agency and self-efficacy necessary to take responsibility for their own learning and hence have difficulty achieving the cognitive changes which are the learning outcomes in these subjects" (Gardner 2017). Thus it cannot be assumed that all students are equally ready for independent study, which is increasingly being conducted online.

In combination with the current context of higher education are the demands to renew engineering education. As Bucciarelli and colleagues pointed out at the end of the 20th century, "what is needed is a new culture of engineering education characterized by active learning, project based learning; integrated development of mathematical and scientific concepts in the context of application…[and] a faculty devoted to developing emerging professionals as mentors and coaches…" (Prados in Bucciarelli, Einstein, Terenzini, & Walser 2000). This need has only increased in the last two decades. Much energy is being directed toward producing a three-dimensional engineering graduate, as opposed to what Wulf and Fisher refer to as "the traditional stereotype of the asocial geek" (2002, p.36). The three dimensions comprise technical competence, personal/professional competence and design-oriented competence. Another way of looking as this is the combination of the technical specialist, the integrator and the change agent, where the integrator reflects the need for engineers who are boundary-crossers and the change agent emphasises the importance of engineers to provide creativity, innovation and leadership (Henley report 2006, p.60).

The constantly shifting landscape of technology and global projects has put pressure on engineering education to embrace the development of students' professional and technical capabilities in ways that incorporate authentic learning and assessment. Project-based learning has long been regarded as one of the more effective ways to develop students' deep and broad understanding of the field in which they are studying. There is strong evidence that problem-based and project-based learning can be successfully integrated into content-laden units of study, both deepening understanding and developing conceptual change, without loss of technical knowledge (e.g. Brodeur, Young & Blair 2002; Gomes & Barton 2005; Hadgraft & Kolmos 2007).

In addition to developing understanding, project-based learning can enhance students' engagement with their university studies. The importance of working in groups and teams is emphasised by transition pedagogy research, which reports connections between first year students" lack of exposure to group work and a less than satisfactory university experience. "In 2014, there was still a large proportion of students who reported never working with classmates outside of classes (26%), never working with other students on projects during class (21%), and never studying with other students (26%). Fewer than one in five students frequently studied with other students. This meant they were less satisfied with their university experience overall, and less likely to achieve high marks in the first semester" (Baik, Naylor & Arkoudis 2015, p.3).

All these complex demands thus require an approach that scaffolds blended learning, acknowledges different prior learning experiences, introduces project-based learning with authentic assessment and begins the process of developing engineering students" professional identity as a three-dimensional engineer.

This project builds on much work that has gone before in the context of developing first year engineering students' technical and professional attributes (e.g. Kavanagh, Neil & Cokley 2011; Mann, Howard, Nouwerns & Martin 2009; Shekar 2014), and particularly studies that have used the Engineers without Borders Challenge as a way of utilising project based learning (e.g. Stappenbelt & Rowles 2009). Although there are similarities between this project and the UWA study reported on by Stappenbelt and Rowles (2009), there are also significant differences. One of the main aims of this project is to introduce students to the concept of critiquing their previous expectations of an engineering identity, and learning to construct an engineering identity that is three-dimensional. A key feature of the approach is the utilisation of learning activities which are scaffolded through pre-class activities, in-class tasks, peer learning and review, and formative assessment. As it is a core first year engineering subject, it is critical that students develop good study practices and are provided with a solid platform on which to build their independent learning. The following section describes the specific context of the research project.

Context

Engineering Communication is a large first year subject with a cohort of between 350-400 students that introduces students to the complexities of communication within engineering practice. Since its inception in the early 2000s, the subject has attempted to provide a range of tutorial based experiences aimed at developing students" professional capabilities in research, academic writing, oral presentations, evaluation of information, teamwork and peer review. Within a supported classroom environment, students are inducted into teamwork and leadership and begin to develop a sense of the nature and scope of engineering work beyond the technical skills often associated in engineering disciplines. In doing so, students" professional identity begins to form early in their academic careers.

Engineering Communication was originally designed as a series of 12 weekly modules allowing for skills development in key communication areas. In class, students were presented with activities and related materials to which they responded in an individual student workbook. Some online materials were provided to support learning; however, most students did not take advantage of the preparatory work as it was not linked purposefully to the tutorial content. Overall learning would culminate in a team literature research project and accompanying presentation based on a prescribed engineering problem. In its original form, Engineering Communication lacked both excitement and authenticity and fell short of the stated aims of the subject.

In 2012 the Engineers without Borders Challenge (EWB) was introduced to give students an authentic design project and the task of developing a solution for a genuine set of stakeholders, the aim being to introduce a broader range and deeper understanding of engineering activities. A firm partnership was formed with EWB which added a new focus and further materials to the subject. Over time the student workbook continued to grow (adding rather than deleting content) offering activities that far exceeded the weekly 3 hour timeslot. At this time there was no serious attempt to encourage pre-class preparation or independent learning as most material was presented in class. A smorgasbord approach to the delivery of content was adopted, allowing tutors to develop their own interpretation on how best to utilise the materials.

An anecdotal review of learning and teaching in Engineering Communication in 2015 revealed a high level of inconsistency across the tutorial classes for both students and tutors. Tutor meetings often revealed this disparity when discussing the range of approaches to any given topic. Although the essential framework (content topics and assessment tasks) was aligned, there appeared to be great discrepancy between what was delivered to students across the classes. In an attempt to allow tutors to develop their own content flavour relevant, the materials had over time become cumbersome and confusing. In short, the need to develop a clear and consistent subject narrative was identified.

In 2016, a move towards a new (shortened) academic calendar and the university's learning model initiative presented an opportunity to obtain support to re-design Engineering Communication. The aim was to retain the original intent, including the EWB Challenge project, while structuring class content and introducing blended learning strategies. This required an audit of all existing content and a rationalisation of materials into 10 weekly modules; each telling its own structured "story" through a series of collaborative in-class exercises and a series of pre-class tasks. While the EWB Challenge project had been established within the subject for some time, the re-design was a significant shift to include a consistent scaffolded approach with a focus on independent learning.

Purpose

The project aims to support students through the institutional model of learning and provide guidance in blended/flipped activities so they are prepared for their engineering studies. The first stage of the project is to provide a solid platform for independent learning at university. Later stages of the project will track students throughout their engineering studies to explore how their engineering identity is developing. It is essential that students in the first year are introduced to the expectations and benefits of the approach used in the University of Technology Sydney's (UTS) model of learning in a subject where there is strong tutor support and flipped and blended learning can be contextualised. Transition is improved as the students gain an introduction to the UTS model of learning and there is scaffolding of blended and flipped learning experiences. Because of the strong tutor support in Engineering Communication, the approach provides students with a solid foundation for independent learning in a blended learning environment which will better prepare them for transition into later year subjects. It also builds in greater "time-on-task", and a sense of capability, which is known to be a key factor in enhancing student satisfaction and in student retention.

Engagement in an interactive, collaborative and supportive learning environment is improved as students are better prepared to participate and learn in class through a range of activities they can access on demand. The approach also significantly impacts students" "time-on-task" as they are expected to prepare for in-class and out of class activities.

Flipped online activities for students, such as pre-class tasks that require students to complete a reading or watch an instructional Youtube clip and answer questions, have been reinforced in the tutorials. This has introduced students to blended learning in Engineering Communication so that students understand from the beginning of semester the importance of interacting with the learning management system (LMS) and with completing the pre-class tasks. Project based learning has been consolidated by teaching and learning activities that centre on the Engineers without Borders (EWB) Challenge project, which further embed the learning to the project by linking it more closely to subject content, therefore making the combination of project and content more relevant. In addition, teaching and learning activities provide feedforward and feedback on the assessment tasks; the assessment tasks have been designed to assist students to learn about project management in the context of the EWB challenge.

The move to standardised modules and the streamlined content of the student workbook attempts to provide a more consistent teaching and learning experience. This is critical in any large subject where there are several tutors and many tutorials, which can result in quite disparate teaching and learning practices and outcomes. In order to ensure that there is a shared understanding about the intended learning outcomes of the subject, workshops for tutors are held at the beginning of each semester. Tutor induction is run in conjunction with EWB to develop common understandings about expectations and the design brief; the social context for the project is set in a workshop with a discussion format.

Approaches to evaluating the subject redesign

One of the intentions of the subject redesign has been to expand engineering students' awareness of the nature of engineering work using project-based learning in the context of the EWB challenge. Another has been to provide both students and tutors with opportunities to adapt to an innovative institutional model of learning which places emphasis on flipped and blended learning. As this is the first stage in a project to track students' developing identity as engineers, and in order to investigate how successfully these intentions have been fulfilled, we conducted a questionnaire of students and tutors. We chose to have open-ended questions to allow student and tutor voices to be heard. The student questionnaire was administered as an in-class activity and all responses were de-identified. There were 150 responses which is a response rate of 46.4%; the student cohort is 323 across 13 tutorial classes. The tutor questionnaire was emailed to the tutors and all responses were returned in hardcopy via a physical drop box, to maintain anonymity. Nine responses were received, which is a response rate of 100%.

Students were asked to comment on changes in their perceptions about the nature of engineering work and of professional attributes, and activities that have assisted in deepening their understanding of these concepts. This can be seen as an indicator of their professional identity development (Buckingham Shum & Crick 2012).Tutors were asked about their perceptions of changes to the subject and the extent to which they could see the development of students' professional attributes.

The anonymised student questionnaire results were compiled by a research assistant and subsequently analysed using Concordance software (Watts 2011) to quantify frequency of terms. This allowed the identification of key themes to emerge. As there were a relatively small number of tutor responses, the results were analysed by the two researchers.

Results

Analysis of student questionnaire

Defining the nature of engineering work

When students define the nature of engineering work the most prominent themes are communication, teamwork, research, and report writing. However, the responses demonstrate a range in complexity such as "I learned that to work as an engineer, I should be disciplined and have good communication and research skills" to "engineering work is not just about communication or design and implementation, it's also about the social, cultural, economic and environmental effect on society [so] engineers should be humanistic and consider lots of aspects". The range of comments reveals the different levels of effective learning that may be taking place in the subject.

50% of students who cite communication, also identify an aspect of teamwork. For example, "engineering work is very concise, communication amongst team members being the key to successful projects". Approximately 5% included activities such as critical thinking, creativity and accuracy.

Four students provide specific statements on how their ideas about the nature of engineering work have changed. Examples include "engineering is a very broad field, broader than I had in mind – a field which requires a lot of teamwork" and "I first thought that engineering requires no communication with other people, but this subject has proven otherwise".

Activities that have helped in understanding engineering work

The most commonly occurring activities listed are writing reports and research skills followed by learning presentation skills and collaborative project work. These topics relate closely to the module content offered in tutorials and students identify more than one activity in over 90% of responses. Comments include: "I have learnt writing, listening, presentation skills and others that have helped me understand engineering work" and "one activity is doing work in groups, being able to interact with other people with alike minds, giving me a taste of what it is like to interact with fellow engineers".

Two examples where students make clear associations with the assessment tasks and their increased understanding of engineering work are: "Task 2a(i) and 2b(i) have significantly impacted on my understanding of engineering work as it emulates the role a team member must perform in his group. By working alone, it taught me to treat my individual work as if it were the whole group's and failing to do so will result in letting down my group members" and "the assessment tasks have helped me greatly to understand how to research effectively on engineering content".

The pre-class tasks are identified as assisting the understanding of engineering work by "creating a scaffold of what is to be learnt in the upcoming tutorial for it to be fully constructed during the tutorial", and "reading so many articles or the text book truly help me a lot".

Pre-class tasks assisted in tutorial learning

Student responses to how the pre-class tasks assist their learning fall into four groups; those that wrote a general comment on the role of the tasks; students who state how they found the tasks useful; students who feel that the tasks are a waste of time; and students who state they do not complete the tasks.

25% of students provided specific information about how the tasks have assisted in tutorial learning, such as: “I would say it’s a nice way of learning because we already know what [is] expected in class” and “it deepens my knowledge and stops time being wasted” and they “stop me from feeling lost for the period of the class”.

Three students claimed the pre-class work is not useful: “not much”, “quite ineffective in improving my tutorial learning” and “in my opinion they have not”. The remaining group of two students did not complete the pre-class tasks and confessed: “I have not been diligent in doing these tasks” and “unfortunately I have not completed the tasks”.

Introduction to professional attributes

55% of students name “communication” as the key professional attribute, which they interpret broadly. Comments such as “being able to market your ideas to an audience” and “be clear when you are speaking” are included in this category. Generally, students do not identify the faculty Graduate Attributes for the subject (Communication and Coordination; Self-management; Engineering Practice in a Global Context) even though these attributes are explicitly named in the introductory lecture and discussed throughout the semester.

The responses demonstrate a trend for students to itemise attributes such as research, teamwork and writing separately from “communication”. For example, 35% of responses listed writing, (including academic writing, report writing and being able to write clear concise reports) in addition to “communication”.

Analysis of tutor questionnaire

Impact of pre-class tasks on tutorial teaching

Overall, there is a mixed reaction to the pre-class tasks. “Some good outcomes but most students have not adapted to the cultural shift”. While the rationale behind the pre-class tasks appears to be accepted by most tutors, the responses indicate a high level of frustration that many students choose not to complete them regularly.

Tutors claim to “spend significant time screening and explaining the importance of the tasks” and it can be “difficult to run the session on the basis that the pre-class work has been completed”. When tasks are not completed, tutors agree that it reduces the effectiveness of the session and students who are motivated to complete the tasks often become disappointed by those who don’t. Additionally, tutors express concern that the pre-class work is seen as not challenging and not compulsory. Therefore, we are “sending a message the [tasks] are not essential to the subject”. Tutors were asked to provide the proportion of students that complete the pre-class tasks most of the time. The reported completion rate was approximately 50% across thirteen tutorial groups.

Tutors who report a higher degree of success in pre-class task compliance agree that students are more engaged and the work done prior to class is helpful to the teaching and learning process. Done well, these tasks “target discussion and direct learning” while “providing background to engage and facilitate activities”. There is an acknowledgement that the pre-class work “changes the way students prepare for class and that there are varying degrees of success depending on the student”.

Key professional attribute introduced in teaching and learning activities

The key attributes identified by tutors represent the common and expected themes of Communication and Coordination. Some tutors expanded these areas to include personal responsibility, self- management, teamwork and working to a standard.

Ways in which professional attributes are developed

All tutors identify teamwork and collaboration as an essential element in the development of key professional attributes with “group work becoming a focal point for almost every tutorial”. As students work through the project requirements “students start to think for themselves”. Project-based learning in this case has “task orientated learning outcomes that are strategically employed within the subject to develop every attribute”.

Tutors place importance on group work as the “element that provides significant learning” and “the need for individual and collaborative organisation in a variety of [tasks] needed to produce the group project report”. “Students, consciously or sub-consciously begin to take roles within their group which often gets disrupted as they begin to understand that they have different aspirations and goals”.

Tutors note the class based activities begin the formation of professional identity along with “understanding more about professional practice and providing a real-world context” to this learning. Comments include: students “develop a professional identity while considering their future as a professional engineer”. This becomes “evident in [student] attitudes towards the portfolio activity at the end of the subject”.

Impact of the changes to the subject

While tutors endorse the EWB Challenge and project-based learning, most raise concerns about the required pre-class tasks and how they are applied to the subject. There is a range of responses to the overall changes to the subject. Some tutors are unconvinced the changes have any impact at all. “I don’t think they have made a significant impact and I do not detect any differences in most students” attitudes or in the quality of the reports”. A contrasting view is that: “recent changes streamline the process and make good links with the subject materials are made”. Two tutors stated they were not sure if the changes had made an impact in their classes or to their teaching.

Ongoing challenges

Tutors are agreed that motivation is a problem for some students in most classes they teach. There is a concern that “some students are not suited to this type of open-ended learning. They want clearer guidelines so they don’t have to take risks” Tutors raise the issue of cultural expectations and the reluctance of particular students to take part in group tasks. The overall sentiment is summed up with “most students are keen and easy to work with but there is always a proportion who do not want to engage”. Another ongoing challenge is ensuring compliance/completion of pre-class tasks. Tutor comments point out that some students struggle to make the cultural shift to a flipped and blended learning model. There may also be a need for cultural shift by tutors to reinforce the need for completion, and to make sure that class time is not spent on doing the pre-class tasks.

Some tutors are concerned about student standards: “there is a real and increasing challenge as the curriculum changes and student standards decrease”. Another tutor comments “students whose language is not sufficient are therefore, achieving a better outcome at the expense of those who carried the team”. A further concern noted “some students are well below university level”.

Discussion and conclusions

Overall, the student responses reflect the diversity of the cohort, the range of learning experiences, the varied levels of engagement, and the differing interpretations of the nature of engineering. This is to be expected in a large first year subject which introduces the students not only to new concepts but to new ways of learning in a new context. It is important to recognise that there are variations in expectations of what is required in university learning and that one size does not always fit all. Students also vary in the speed with which they make connections between in-class and out of class learning.

It was pleasing to see the growing awareness of the nature and complexity of engineering work and a shift away from a purely technical focus. In-class activities such as group work and collaboration reinforce this broader understanding, which starts to build a sense of professional identity. This is evidenced by both students and tutors identifying the importance of these activities in developing professional attributes.

As an introductory subject, Engineering Communication serves an important purpose by inducting engineering students into the university model of learning and commencing the development of their professional identity. However, it is crucial that later year subjects continue to develop students’ professional attributes in conjunction with the development of their technical knowledge.

The range of student and tutor response to the pre-class tasks indicates that a significant proportion of students and tutors consider that these tasks add value to their learning, and some students could clearly articulate the benefits. For some students, the pre-class tasks did not contribute to their learning and this suggests that there is work to be done in assisting students and tutors to make the cultural shift to flipped and blended learning.

The divided opinions of the tutors regarding the changes to the subject design and delivery reflect the challenges in delivering a standardised teaching and learning experience across a large-scale subject. A consistent approach requires a shared understanding of and commitment to providing rich learning experiences.

In conclusion, these results suggest a need for a high level of collaboration between tutors to develop a clear sense of direction and purpose; students should also be part of this process and should have an opportunity to contribute to subject design. The next stage of the project will track how students develop their professional identity in the context of project-based learning as they progress through their degrees, and will explore the potential of learning analytics to map this development.

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The Rise of Humanitarian Engineering Education in Australasia

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SESSION S3: Integrating Humanitarianism in Engineering Education

CONTEXT Since the early 1980's, numerous organisations seeking to utilise engineering to address humanitarian and development challenges have been established including Engineering for Change, Engineers Against Poverty, Engineers for Overseas Development and national Engineers Without Borders and RedRs. This has contributed to the growth of humanitarian engineering education programs and initiatives in countries including the USA, UK and Canada from the early 2000's. Similarly, humanitarian engineering education courses and initiatives have been established in Australian and New Zealand.

PURPOSE This paper details the growth of humanitarian engineering education programs and initiatives in Australasia since 2006 leading to the current state of the field. From this opportunities for further growth and development will be identified.

APPROACH Student and university participation data drawn from national programs as well as details of current and planned university offerings is used to identify the growth in humanitarian engineering education in Australia and New Zealand. Outcomes from a collaborative cross-institutional workshop are used to identify priorities and opportunities for growth and development.

RESULTS Although isolated initiatives have been delivered under a variety of terms, the current growth of humanitarian engineering education dates back to the launch of the EWB Challenge in 2007. Since 2015 there has been a dramatic increase in the scale of offerings and engagement with the establishment of the EWB Humanitarian Design Summits and introduction of Australian Federal Government support for mobility programs. This has led to the development of elective courses in the area and formal award programs emerging from 2016, with at least five Australasian universities offering or planning award programs. Broader impact is demonstrated by student demographic data which clearly indicates a significantly higher percentage of female engagement in the area than typical for engineering.

CONCLUSIONS Opportunities exist to continue to expand the field and its impact including educational research and development, engagement with professional bodies, and advocacy. This will contribute to leadership and the potential for humanitarian engineering to achieve positive impacts for communities and individuals in Australasia and internationally.

KEYWORDS Humanitarian engineering, development engineering, graduate outcomes

Introduction

The role of engineering in national development and providing benefits to society has been articulated since the first civilian professional associations began in the early 1800’s (Institute of Civil Engineers, 2017). The engineering profession has sought to bring these benefits to various short- and long-term humanitarian interventions as part of the growth of coordinated responses and international development since the 1960’s (Lucena and Schneider 2008). From the early 1980’s this led to the establishment of dedicated organisations utilising engineering to address humanitarian and development challenges including Engineering for Change (EfC), Engineers Against Poverty (EAP), Engineers for Overseas Development (EOD), national Engineers Without Borders (EWB) and RedRs (UNECSO 2010). These organisations work across the humanitarian spectrum, from immediate disaster response, through recovery and stabilisation, to long-term community and infrastructure development, disaster planning and preparedness, and capacity building (Greet 2014).

Many of the engineering organisations working in development were established by engineering students or university staff. This has contributed to the growth of humanitarian engineering education programs and initiatives in countries including the USA, UK and Canada, which engage students in the area and prepare them for future roles (Lucena and Schneider 2008, UNECSO 2010). In Australasia, individual courses and initiatives within humanitarian engineering education were established in the early 2000’s and have been growing since 2007.

This paper reviews the integration of humanitarianism in engineering education in Australasia and details the growth of humanitarian engineering education programs and initiatives since 2006. It first discusses humanitarian engineering including a working understanding of the term and overview of some of the key organisations. Data on university and student engagement is provided from national programs and university offerings. Finally, opportunities, challenges and priorities for continued growth and support are identified.

What is humanitarian engineering?

The term *humanitarian engineering* (HumEng) only emerged in Australasia with Engineers Australia’s, the peak professional body, *Year of Humanitarian Engineering* in 2011. Prior to that, terms such as *development engineering* were used (Turner et al. 2015). The first reference to the term at an Australasian Association for Engineering Education (AAEE) conference was in 2013, previously *EWB* was used as a synonym for the field.

The understanding of HumEng that has emerged in Australia since 2011 encompasses a wide range of contexts and locations, from disaster response through to community and technology development, both internationally and domestically. HumEng is taken as the application of an engineering discipline, such as civil or mechanical, to a specific humanitarian or development context or response. In this way, it is an application area requiring additional dedicated knowledge, skills, attitudes and competencies rather than a unique discipline. This is a broader understanding than other countries, for example in the USA HumEng encapsulates predominately non-US development while in the UK it focuses on disaster response and recovery. (Turner et al. 2015)

While there has always been individual *humanitarian engineering education* (HumEngEdu) offerings available to students, the first structured programs providing multiple engagements emerged from universities in the USA in the early 2000’s (Bixler et al. 2014, Dean and Van Bossuyt 2014). In Australasia, a small number of not-for-profit organisations have been leading the development of education and training initiatives in the area. RedR Australia was established in 1992 to make engineering available to disaster relief and has since expanded to offer expertise across all aspects of humanitarian emergencies (RedR Australia 2017). RedR has offered short-course professional development training since 1998 and has recently expanded to support tertiary education and as of mid-2017 has partnerships with five Australian universities across a range of humanitarian response aspects, not only engineering (RedR Australia 2017).

The first wide-scale HumEngEdu offerings in Australasia were developed by Engineers Without Borders Australia (EWB-A). EWB-A, which was established as an independent national organisation in 2003, has a focus on community development in Australia and the surrounding region. EWB-A delivers three programs (discussed below) targeting tertiary education. Engineers Without Borders New Zealand (EWB-NZ), another independent national EWB organisation, established in 2008, provides three programs to universities in NZ. Since 2016, further offerings have emerged in Australasia. The first Australian chapter of Engineering World Health (EWH), a US-based organisation to improve healthcare delivery in low-income countries, operates at the University of New South Wales (Engineering World Health 2017). The Laika Academy provides short-term study abroad opportunities covering topics interfacing with HumEng including design for social change, sustainable development, social enterprise and community rebuilding (Laika Academy 2017).

Humanitarian engineering education in Australia and New Zealand

The opportunities provided by external organisations are incorporated into universities programs as institutions deem appropriate. Universities expand on those to develop their own opportunities depending on resources, expertise and demand. However, the largest programs, in terms of duration and reach, are those offered by EWB-A which are detailed below. Data from the EWB-A programs combined with a summary of university courses and programs, will be used to investigate the overall scale of HumEngEdu in Australasia. While this data will not be comprehensive, it will provide an indication of growth and overall trends.

The EWB Challenge

The EWB Challenge, coordinated by EWB-A, is a design program delivered in partnership with universities which introduces concepts of humanitarian engineering to students in addition to crowd sourcing ideas for community based organisations. Each year the EWB Challenge focuses on projects identified in conjunction with one of EWB-A's community based partner organisations. The EWB Challenge provides a platform that enables universities to meet learning outcomes associated with global citizenship, professional practice and sustainability. Universities embed the EWB Challenge into first year engineering curriculum, typically within an introduction to design or engineering unit, adapting the program to meet the learning outcomes of the unit in which it is embedded.

The EWB Challenge has arguably been the most influential program contributing to the rise of HumEngEdu in Australasia. The EWB Challenge was introduced at a time of increased pressure to renew first year engineering curriculum and adopt education pedagogies such as project based learning to meet changing education demands (Jolly 2014). The EWB Challenge provided real world project briefs and supporting resources, such as data, photographs and report marking criteria, making it appropriate for universities to embed. The EWB Challenge provided a common platform for universities to compare and evaluate their approaches to first year engineering education as seen in a 2014 Office of Learning and Teaching report by Jolly (2014):

> "The Challenge is unique [at the time of the evaluation] for engineering in that, like some approaches in medicine, agriculture and elsewhere, it has a strong and distinctive focus on the development of graduate attributes related to social, cross cultural and ethical responsibilities in a global context." (Jolly 2014)

The EWB Challenge was launched as a national program in 2007 in partnership with 21 universities and reached approximately 3,500 students, see Figure 1 A). It rapidly expanded and in 2017 reached 9,040 students at 28 universities including the off-shore campuses of Australian institutions, and remains the largest HumEngEdu initiative in Australia and New Zealand. In 2011 the EWB Challenge program was introduced to the UK where the program, referred to as the Engineering for People Design Challenge, is co-ordinated by Engineers Without Borders UK (EWB-UK). In 2016/2017 this reached 4,600 students across 23 universities (EWB-UK, 2017). The EWB Challenge was supported by university registration fees subsidised by sponsorship from BHP Billiton Sustainable Communities from 2008 to 2015. Since then the program has been funded solely by university registration fees.

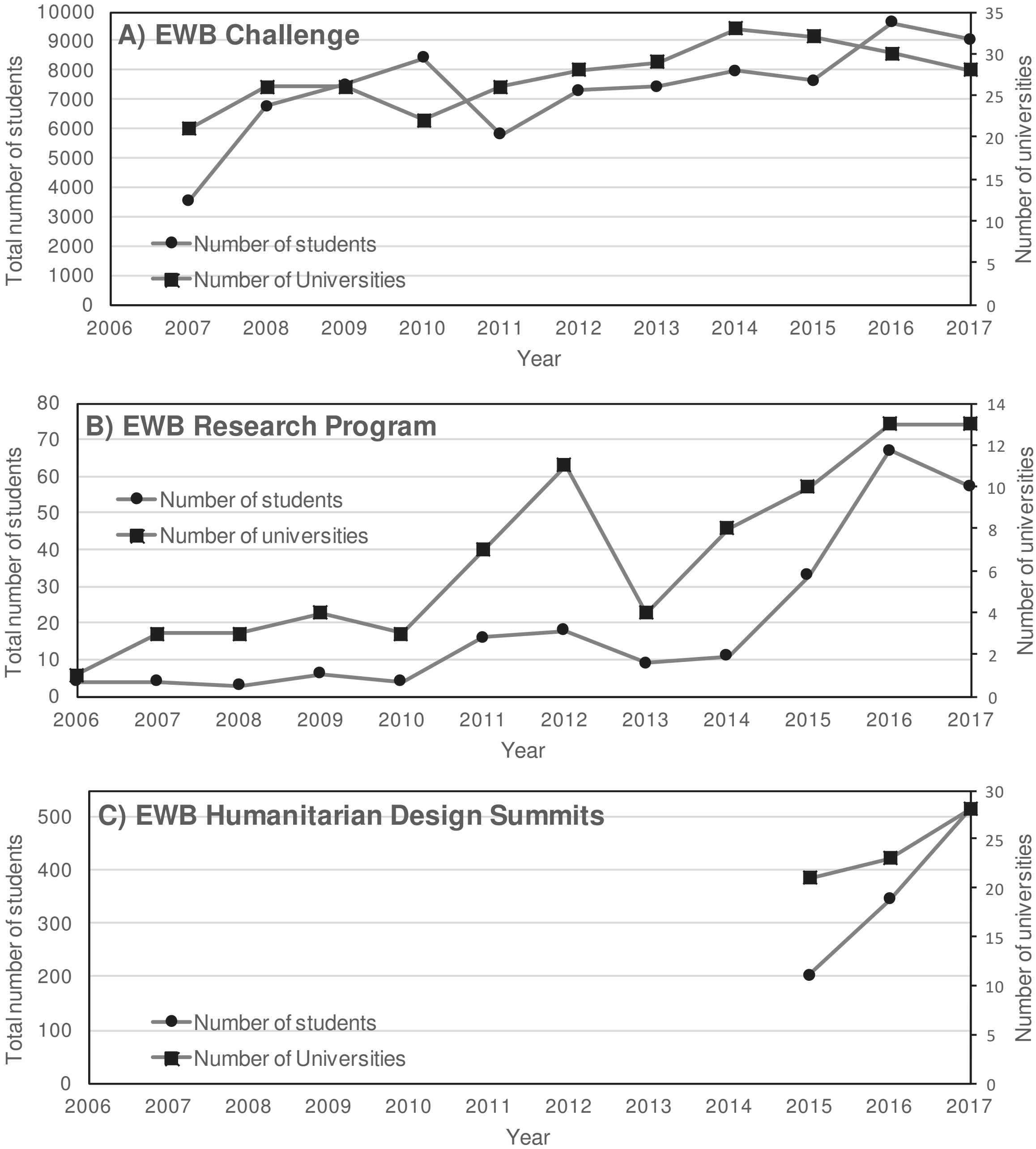

Figure 1: Total number of students and universities in Australasia participating in A) the EWB Challenge, data supplied by EWB-A from university registrations where universities self-report student numbers, B) the EWB Research program, data supplied by EWB-A from student registrations and C) the EWB Humanitarian Design Summits, data supplied by EWB-A from student registrations. (Note: data for 2017 is estimated)

EWB University Research Program

The EWB University Research Program, established by EWB-A in 2006, engages students, academics and community organisations in collaborative research projects. Beyond the development of new humanitarian knowledge and technologies, the program provides university students with an opportunity to grow humanitarian skills and social impact motivation before entering the workforce. The real-world context is vital with all projects targeting opportunities identified by practitioners and community development organisations working towards sustainable development in the Asia-Pacific region. The EWB University Research Program has conducted over 200 collaborative research projects in total as shown in Figure 1 B). In 2017, the program was delivered in partnership with 13 universities engaging 57 undergraduate researchers. The program was initially run through volunteer support while since 2009 the program management has been part of a paid role. A similar program is supported by EWB-NZ targeting universities in NZ.

EWB Humanitarian Design Summits

The EWB Humanitarian Engineering Design Summit program is a short-term study aboard opportunity designed to provide students with an experience to develop a deeper understanding of the role design and technology plays in creating positive change within communities. Students work through a human-centred design cycle over two weeks culminating with presentations of ideas to community members and organisations. A key component of the learning is ensuring that students participate in a genuine, immersive rural experience with a community. To deliver the program EWB-A partners closely with local grass-roots organisations that have a working relationship with communities.

The program was inspired by the hands-on International Development Design Summit at Massachusetts Institute of Technology's (MIT) D-Lab, leaders in human-centred co-design and community creative capacity building. Recognising the need for professional practice training and building on the experience of EWB's previous pilot study-tours, the Humanitarian Design Summit was launched 2015. The program has expanded to deliver 12 programs a year in six countries and has a network of over 800 alumni with university and student participation shown in Figure 1 C). The program collaborates with more than 25 Australian universities and is recognised through the Australian Government New Colombo Plan. EWB-NZ also runs similar opportunities for New Zealand university students.

Measured learning outcomes for students include development of personal and professional skills, application of knowledge in a development context, recognition of development practices and use of human-centred principles. The program delivers outcomes through workshop sessions, cultural immersion activities and student-led investigations. The program includes Academic Fellow positions allowing university staff to participate and gain first-hand experience in humanitarian contexts, which they can utilise within their teaching practice (Brown et al. 2016).

University humanitarian engineering offerings

Current and planned HumEngEdu course and program offerings from a range of Australasian universities are shown in Table 1. This is not intended to be a complete list and is provided from institutions involved with the Humanitarian Engineering Education Network of Australasia (described below). It focuses on university level tertiary education only, excluding the VET sector and professional development. This includes the two currently available award programs at the University of Canterbury and the University of Sydney.

Most of the universities engaged with HumEngEdu, shown in Figure 1, are involved with more than one initiative with the overall number of universities in Australasia involved with HumEngEdu in the order of 30. This means at least 60% of the universities offering engineering in Australia and NZ are involved with HumEngEdu in some form (EA 2017, Education NZ 2017). From Table 1 at least five of these universities currently offer, or plan to offer, award programs under the term Humanitarian Engineering. All of these award programs are complementary, or added, to an existing bachelor's degree in engineering, mostly commonly in the form of a four-unit program (called a minor or major depending on institution). This aligns with the understanding of HumEng in Australasia, as the conscious application of a base engineering discipline to humanitarian contexts or responses.

Table 1: Selection of humanitarian engineering education university offerings, including current status of proposed or planned programs

University	Offering	Structure	Status / notes
The Australian National University	Master of Humanitarian Engineering	Proposed vertical double degree with a Bachelor of Engineering.	Proposed, if approved would be available from 2019 to all engineering students.
RMIT University	Elective course in Master of Engineering	12-credit point, first year dedicated humanitarian engineering elective	Currently offered.
Southern Cross University	Compulsory course in Bachelor of Engineering	12-credit point, first year compulsory course.	Focuses on a humanitarian engineering project (independent of the EWB Challenge).
Swinburne University of Technology	Social Impact Pillar and compulsory service learning in Bachelor of Engineering Practice	Social impact is one of 4 compulsory pillars. 15% of student workload is dedicated to service-learning project work.	Bachelor of Engineering Practice commences in 2018 and integrates social impact across the degree rather than a separate focus.
The University of Adelaide	Minor in Humanitarian Engineering	Six courses, 2 as double-badged, 4 dedicated courses from a list of 7.	Approved to commence in 2019 available to all engineering students.
University of Canterbury	Diploma in Global Humanitarian Engineering	Mix of cross-credit courses, non-engineering electives and capstone course	Commenced in 2016.
The University of Melbourne	Minor in Humanitarian Engineering	Within the 2-year Master of Engineering.	Proposed, if approved would be available from 2019 to all engineering students.
The University of New South Wales	Courses in Humanitarian Engineering	Two new humanitarian engineering focused courses.	To commence 2018, available to all engineering students.
The University of Sydney	Major in Humanitarian Engineering	Four compulsory courses (3 engineering, 1 arts).	Commenced 2017, first graduates expected 2018, available to all engineering students.
University of Wollongong	Scholars Research Project	6-credit unit course.	Students undertake field work in Rwanda.
University of Technology Sydney	Summer Intensive Design Studio	Design studio focused on humanitarian engineering.	To be offered for the first time in the 2017/18 summer session.

Impacts of humanitarian engineering education

The growth of HumEngEdu has already had impact on engineering education and professional practice in a number of positive ways. One of the strengths of HumEngEdu is a greater level of engagement of female students. Female participation in the EWB University Research program since 2006 is 38% while the female participation in EWB Humanitarian Design Summit since being recorded from mid-2016 is 45% (data supplied by EWB-A). Female applicants make up 41% of the total EWB Humanitarian Design Summit applications, suggesting female applicants are more likely to be accepted as they are of higher quality and articulate stronger motivation statements. These compare to female participation of 12.4% of the engineering workforce and the 15-20% common in undergraduate engineering studies (Engineers Australia, 2017). Similar trends are seen at individual institutions, for example at the ANU female participation in optional or elective HumEngEdu since 2007 is 33% compared to an overall female participation of 22% (data supplied by ANU).

Another strength of HumEngEdu is its alignment with recent changes to the portrayal of engineers and additions to Engineers Australia's strategic plan and purpose. To the purpose in their previous strategic plan (2014/15 - 2016/17), "*We are the global home for engineering professionals renowned as leaders in shaping a sustainable world*", the 2017/18 - 2019/20 strategic plan has added *"Engineers Australia shapes the future of Australia - creating happy, healthy, prosperous and sustainable communities*" along with a strategy to "*advance the science and practice of engineering for the benefit of the community*" (EA, 2017a).

Across the growth of HumEngEdu a number of limitations and challenges have been encountered. One of these, the cost of participating in immersive study experiences such as EWB Humanitarian Design Summits, has been eased through the Australian Federal Government New Colombo Plan (NCP) scholarships. Launched in 2014, these are designed to support experiences in the Indo-Pacific and have certainly contributed to the growth of programs offered by EWB-A and the Laika Academy. However, NCP scholarships are limited to domestic students and may still leave a significant funding gap for some students.

As highlighted in international research (such as VanderSteen et al. 2009), another challenge is the ethics and appropriateness of students engaging in development and community work. This must continuously be considered, in particular in relation to resources committed and outcomes received by the parties involved. Considerations are taken into account through the design of programs, with students in the EWB University Research Program and EWB Humanitarian Design Summits only engaging in development through scaffolded and mentored experiences and not independently leading a project. The understanding of HumEng within Australasia emphasises not only international work, as in some countries, but highlights domestic development challenges and inequities.

An early challenge in HumEngEdu in Australasia was the expertise of academics and educators, with many coming from engineering backgrounds with little or no development experience. The Academic Mentor roles within EWB Summits were designed with this in mind, to provide field experience, while further capacity is being built through annual EWB Challenge academic workshops, dedicated HumEng academic positions, the establishment of network of educators (see below) and the expertise provided by EWB-A and RedR.

Opportunities and recommendations for the future

To support the growth of HumEngEdu, the Humanitarian Engineering Education Network of Australasia (HEENA) was formed at the start of 2017. Involving more than a dozen universities this serves as a platform for academics, educators and practitioners involved with HumEngEdu initiatives to support one another, build on strengths and overcome limitations. In September 2017, this network held a half-day discussion exploring the growth of HumEngEdu, attended by eight Australian universities and two education providers. From this discussion, a number of priority areas were identified to support growth and delivery of programs at individual institutions, continue cross-institutional collaboration, and demonstrate national leadership. The priority areas identified were:

1. The establishment of a national Advisory Board to provide advocacy, leadership and engagement for the further growth and development of HumEng.
2. Engagement with EA to ensure alignment of HumEng education, professional development and practice with EA structures, recognition and processes.
3. Education design and delivery, including the development and sharing of course material, curriculum approaches and education research. This will seek to build an evidence base to evaluate the impact of HumEngEdu on graduate employability and partners to support continuous improvement and best practice.
4. Research and funding, to support research and development in the area and opportunities for collaborations to support broader impact beyond education.

Many of these aims build on existing work in the area in Australia (such as Greet 2014, Smith et al. 2015, Turner et al. 2015) and internationally (for example Bixler et al. 2014, Dean and Van Bossuyt 2014, VanderSteen et al. 2009). They recognise that work and education in humanitarian contexts is highly complex and multi-disciplinary. In most cases, it involves engagement and work with potentially vulnerable and at risk individuals and communities requiring the highest level of ethical practice and conduct. A shared understanding of HumEng and its application is required to enable appropriate delivery of education, research, services and impact, which is a focus for HEENA. This will promote further growth aligning with the newly articulated purpose of EA and to create a new generation of engineers able, and willing, to emphasis positive community benefits in all engineering work.

Conclusions

Ten years after the wide-scale introduction of the EWB Challenge and EWB University Research Program, HumEngEdu is now common across universities in Australia and NZ. There has been a step-change in the integration of humanitarianism into engineering education since 2015 with at least 60% of universities in Australasia offering engineering involved in HumEngEdu in some form, two currently delivering award programs and at least three more planning award programs. This increase has been driven and supported by student interest, a recognition of the global nature of engineering, and new opportunities for students to be involved in study abroad programs. The increase has demonstrated impacts on gender diversity in engineering education with programs and initiatives typically reporting 50% or higher female participation than on average.

A network has been established by universities and organisations working in HumEngEdu to support its continued growth. This has led to priority areas being identified for further collaborations, discussions and leadership to ensure HumEngEdu is delivering on its potential to support student outcomes and achieve positive impacts for communities and individuals in Australia, NZ and internationally.

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Engineering Creativity – How To Measure It?

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SESSION S2: Educating The Edisons Of The 21st Century

CONTEXT Scholars have been interested in sources of creativity and the ways to enhance it for centuries. The domain of human creativity has been extensively researched for over 100 years. Nonetheless, the researchers have neither agreed on the definition of creativity nor on the proper methodologies to measure it (Lubart & Besançon, 2016; Simonton, 2016). Some scholars suggested that creativity means different things in different domains (Baer, 2016; Weisberg, 2006) and argued that the definitions and the means to measure creativity need to be domain specific.

PURPOSE Establishing the definition of engineering creativity and devising the criteria and the means to assess it is of utmost importance for the development of engineers for the 21[st] Century. Unless engineering educators are able to accurately measure creativity skills of their students, they will be unable to establish ways to nurture creativity skills.

APPROACH Research literature relevant to creativity in the domain of technology is reviewed in order to establish how creativity is defined and how it is measured in engineering. Legal grounds of patentability and patent authorship are analysed. Findings are systematised and reflected upon.

RESULTS The following definition of creativity for the engineering profession is proposed: "*Engineering creativity is the* ***ability*** *to generate novel solution ideas for open-ended problems, ideas that are not obvious to experts in a particular engineering discipline and that are considered by them as potentially useful*".

Based on the definition, it is proposed to measure engineering creativity by engaging subjects in generating ideas for open-ended problems and counting (i) the number of independent ideas proposed by the subject as well as (ii) the breadth of these ideas. It has been posited that the eight dimensions of MATCEMIB (Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular and Biological) is the most suitable means to 'count' the breadth of ideas.

CONCLUSIONS In order for engineering education to judge on successes of their programs in enhancing students' creativity skills and to establish which teaching methods are the most efficient for the purpose, (1) suitable definition of engineering creativity that is agreed upon by engineering educators as well as (2) reliable means to measure engineering creativity is needed. This paper proposes both a suitable definition of engineering creativity and suggests the measures for creativity assessment that are adequate for the engineering profession.

KEYWORDS Creativity, engineering creativity, assessment, problem solving, engineering, engineering education.

Introduction: creativity is domain specific

Both Pablo Picasso and Nikola Tesla are known as extremely creative individuals. The former created art innovations, the latter – engineering marvels. Could the creations of Picasso be measured by the same gauge as developments of Tesla? Over many years creativity scholars tried to define and measure creativity as a general skill. It was expected that this general creativity skill is identical in all areas of human activities and, therefore, transfers from one domain to another. As a result, numerous tests that 'measured' the level of this general creativity were developed. Cropley mentioned that by the end of the last Century at least 255 instruments to assess creativity were in existence (Cropley, 2000). Thys, Sabbe and De Hert (2014) reviewed research publications on creativity tests over the last six decades. They analysed 121 publications and discovered 111 measures of creativity used by the authors. Thys et al. categorised the instruments into four groups in accordance with the 4P model of creativity that was proposed by Rhodes more than 50 years ago (Rhodes, 1961). These model subdivided creativity into four Ps (facets): (i) creative Person, (ii) creative Process, (iii) creative Product and (iv) creative Press (conditions).

The popularity of the 4P model amongst creativity scholars resulted in development of instruments to assess each of the four facets of creativity. As a result, only a minority of the instruments to measure creativity directly tested subjects' performance (Belski, Hourani, Valentine, & Belski, 2014; Sarkar & Chakrabarti, 2011). Instead the instruments engaged subjects in surveys, self-reports or relied on psychometric tools, nominations by experts, supervisor evaluation and peer judgement (Carpenter, 2016).

Over the last two decades more and more scholars posited that creativity is domain-specific (Baer, 2015) and that being creative in one domain does not inevitably make a person creative in another domain (even if this second domain is adjacent to the first) (Baer, 2012; Weisberg, 2006). The domain specificity of creativity is also supported by publications that demonstrated domain specificity of creativity training and discovered negligible transfer of the creativity training gains to other knowledge domains (Baer, 2016). These findings question a utility of any universal instrument of creativity measurement. They advocate for the need of a special instrument that would enable to accurately assess creativity for the engineering profession.

Measuring creativity in engineering

Owens' battery of tests

Engineers have been trying to develop creativity assessment instruments for a long time. Owens, Schumacher and Clark, who proposed a battery of tests to measure creativity in machine design over 60 years ago (Owens, Schumacher, & Clark, 1957) mentioned that some earlier tests were developed by Harris and Simberg from General Motors. These tests were devised to increase "*the supply of potential talent* [to industry] *either through appropriate training or through the discovery of conditions optimally conducive to the problem-solving process*" (p.297). Owens *et al.* did not define engineering creativity explicitly and stated that they were exploring "*a problem-solving, goal-oriented, utilitarian sort of ingenuity…"* (p. 301).

The battery of test developed by Owens *et al.* consisted of four components: two survey instruments and two completion type tests. The Personal Inventory component (PI) contained 197 items that covered interests, personal experiences, opinions, etc. The Personal History form (PH) was made of 48 questions that were related to personal background. Scoring of the PI component and the PH form were similar. It was related to the number of responses that were typical to that of the creative engineer. The Power Source Apparatus test (PSA) engaged a subject in sketching as many intervening mechanisms as possible for the given power source and the motion sequence. The PSA performance was evaluated by the absolute number of solutions and the number of 'workable' solutions proposed. The Application of Mechanisms test (AMT) required a subject to suggest as many types of mechanisms as possible that a given (sketched) mechanism can be a part of. The AMT performance was measured by a number of suggested mechanisms.

Owens *et al.* validated their battery tests by engaging 295 engineers from 31 industrial firms. Creativity skills of the participating engineers were established on the basis of two criteria. The first criterion was related to the creativity level that a work supervisor (chief engineer) assigned to each individual engineer from his company that participated in the experiment. The second was a number of the US Patens that an individual subject was the (co) inventor of. The number of patents was established by means of the PI component that directly asked subjects to report their US Patents.

Twelve years later Owens reported on the longitudinal outcomes of creativity assessment using the above-mentioned battery of tests (Owens, 1969). He compared actual achievement of 938 engineers in 1964 that, being students of mechanical engineering, completed the battery of tests in 1955. He also used the outcomes of tests on mental ability and scholastic aptitude that were administered by the American Council on Education (ACE) in 1953. One hundred and sixty seven engineers that participated in the 1964 study completed the ACE tests as college freshmen in 1953.

Owens' 1964 evaluation comprised two inventories: the Life History Questionnaire (LHQ) that consisted of 181 items related to the subject's experience and demographics; and the Job Environment Survey (JES) that was expected to assess the "research climate" and consisted of 80 questions. As in the study of 1957, Owens' main criterion of creativity was the number of patents and patent disclosures reported by the participant. The number of workable solutions proposed by a subject in the PSA test as well as the number of overall solutions suggested by the subject were found to predict the creativity level achieved by an engineer much more accurately than AMT and the tests of mental ability and scholastic aptitude.

Purdue Creativity Test

Another test to evaluate engineering creativity was proposed by Harris. This test is also known as the Purdue Creativity Test (PCT) (Harris, 1960). Harris defined creativity in engineering as "*the ability to produce a number of original ideas when confronted with problematic situation*" (p. 254). Harris assumed that creative engineers (i) are able to produce more ideas, (ii) can change their frame of reference easier and quicker, (iii) more able to produce uncommon ideas and (iv) better able to visualise in space.

The PCT instrument utilised three types of questions. The first type expected a subject to list as many uses for a pictured object as possible. The second type asked of possible usages of two objects pictured together. The third expected a participant to suggest as many possible options of an object that was presented in another picture. The PCT measured creativity with the Creativity Score that was a sum of scores for Fluency (number of different ideas), Flexibility (score based on the number of different categories of solution ideas) and Originality (score based on the weighting of the different categories). The PCT was developed through analysis of responses of 345 students at Purdue University. The Creativity Score was validated by 64 product development engineers from the automotive industry. Harris found that the Originality score highly correlated with the Flexibility score and suggested that the former can be dropped from the test altogether.

The PCT and the Owens battery test were developed for selection of engineers in jobs that required novel problem solutions. Because of this practical purpose and an openly engineering focus of the tests they have not been used much by creativity scholars.

Creative Engineering Design Assessment

In the last decade another test of engineering creativity, the Creative Engineering Design Assessment (CEDA) was proposed by Charyton, Jagacinski and Merrill (2008). Charyton *et al.* advocated that the Owens' battery of tests as well as the PCT only assess divergent thinking skills and, therefore, do not adequately measure engineering creativity that demands much broader cognitive skills. CEDA was developed to evaluate creative skills of engineering designers more holistically. The author intended to assess problem finding as well as problem solving. Therefore, as posited by Charyton *et al.*, CEDA incorporates evaluation of both skills in divergent and convergent thinking and is more accurate than other measurement instruments of engineering creativity. Charyton *et al.* have utilised the 4P model of creativity but did not offer the definition of creativity explicitly. They have only indicated their view on the Process P: "*creative process is defined as using divergent thinking, convergent thinking, constraint satisfaction, problem solving and problem finding to create a design*" (p. 149).

The CEDA evaluation engages a subject in sketching designs "*that incorporate one or several three-dimensional objects, list potential users (people), and perform problem finding (generate alternative uses for their design) as well as problem solving in response to specific functional goals*" (p.148). The CEDA subjects are given 25 minutes to consider five design problems. The CEDA score is a sum of individual scores on Fluency (number of responses), Flexibility (number of response categories) and Originality (qualitative number assigned to the entire problem). It is important to note that only up to four design proposals (responses) per problem are scored. Therefore the CEDA subjects are instructed to provide not more than four designs per problem.

In 2008 Charyton *et al.* (2008) reported using CEDA to evaluate creativity of 58 engineering students and 59 students of psychology. In a follow-up study Charyton and Merrill (2009) engaged 61 first year engineering students and 21 non-engineering students in the CEDA sessions. In both studies the authors compared the CEDA scores with the outcomes of the following three instruments: (1) Creative Personality Scale (CPS) (Gough, 1979), (2) Creative Temperament Scale (CTS) (Gough, 1992), and (3) Cognitive Risk Tolerance Survey (CRT). Although the authors of both the 2008 and the 2009 studies evaluated CEDA assessment of engineering creativity as reliable, neither study found any correlation of CEDA scores with that of CPS, CTS or CRT.

Testing engineering idea generation

Over the last five years the team led by Belski reported on the outcomes of idea generation experiments that engaged over 500 engineering students from six countries (Belski et al., 2015; Belski et al., 2014; Belski, Livotov, & Mayer, 2016). All students were asked to generate as many ideas as possible for the same open-ended problem. Student performance was assessed by two criteria: (i) the Number of distinct ideas proposed and (ii) the Breadth of the proposed ideas. The former criterion was practically the same as the number of ideas in the Owens' PSA test and Fluency that were used by both PCT and CEDA. The latter criterion was similar to that of Flexibility utilised by PCT and CEDA. Breadth was defined much more formally than Flexibility. To determine Flexibility of ideas it was necessary to devise the list of response categories and to decide on the maximum number of categories for assessment. Breadth had been defined to contain eight 'dimensions' of technology, each corresponding to a specific group of technologies: Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular and Biological (MATCEMIB). A student, who suggested ideas that used three of the eight dimensions, received the Breadth score of 3. Her colleague that proposed solution ideas that utilised five dimensions – the Breadth of 5. Belski *et al.* argued that the Number of distinct ideas proposed and the Breadth of these ideas can adequately assess student's divergent thinking ability (Belski et al., 2015). Belski *et al.* did not provide their definition of creativity.

Engineering creativity and patentability

The need of a common definition of engineering creativity

In order to measure anything accurately it is necessary to (i) explicitly define what is to be measured and (ii) establish the means and the units of measurement. The authors of the above-mentioned instruments that were developed to assess engineering creativity did not use the same definition of engineering creativity. Moreover, only Harris offered the definition explicitly: "*the ability to produce a number of original ideas when confronted with problematic situation*" (Harris, 1960, p. 254). Owens *et al.,* Charyton *et al.* as well as Belski *et al.* were not very clear with their definitions. Owens *et al.* tried to measure "*a problem-solving, goal-oriented, utilitarian sort of ingenuity…"* (Owens et al., 1957, p. 301). Charyton *et al.* focused on the creativity process and tried to assess divergent and convergent thinking as well as problem solving and problem finding skills. Belski *et al.* considered only the divergent thinking skills. Clearly, the absence of a definition of what creativity means for the engineering profession holds the development of adequate measurement instruments. What can help in establishing such distinctly engineering definition of creativity?

Engineering profession is in a unique position regarding the definition of creativity. It is one of a very few fields of human activity that has been judging the level of creativity by the formally established rules for quite some time – by means of rules of patentability. Today the question on what can be considered as novel creation in engineering and what cannot, does not seem difficult to answer. Although criteria of patentability differ a little from country to country, they offer a universal approach to the definition of creativity for the engineering domain. It needs to be noted that the validity of patentability as a criterion of engineering creativity did not change in the last 60 years. Owens *et al.* used the US Patent count as the criterion of creative engineering performance for validating his battery of tests in 1957 and in 1964.

Patentability and creativity

Patent laws usually require that, for an invention to be patentable, it must:

A. Be *novel*

B. *Involve an inventive step* (European and Australian patent laws) or *be non-obvious* (United States patent law)

C. *Be able to be made or used in an industry* (Australian patent law) or *be susceptible of industrial application* (European patent law) or *be useful* (United States patent law).

Let us consider the meaning of each of the three criteria separately.

Novelty

In accordance to the Patent Manual of Practice & Procedure (IP Australia, 2017) there is only one test for novelty:

> *"The test for determining whether an invention lacks* ***novelty*** *is the "reverse infringement test" as set out in Meyers Taylor Pty Ltd v Vicarr Industries Ltd (1977) CLR 228 at page 235; 13 ALR 605 at page 611, where Aickin J stated:*
>
> *"The basic test for anticipation or want of novelty is the same as that for infringement and generally one can properly ask oneself whether the alleged anticipation would, if the patent were valid, constitute an infringement.""*

In other words, in order for anything to be novel, an expert in the field must conclude: "I have not been able to find anything like it!"

Inventive step

As per the Patent Manual of Practice & Procedure (IP Australia, 2017) an examiner can determine lack of **inventive step** if:

"the claimed invention is one of:

- *a technical equivalent;*
- *a workshop improvement;*
- *a special inducement or obvious selection; or*
- *an obvious combination of features of common general knowledge."*

This means that in order to satisfy the criterion of *inventive step*, the invention (i.e. solution to a problem) must not be obvious for an expert in the technological field of the invention. So an expert in the field is expected to conclude: "It is interesting!"

It is important to note that in order to pass the criterion of inventive step a solution needs to solve an open-ended problem. It is highly unlikely that a solution to a closed-ended problem in a particular engineering field will not be obvious for an expert in this domain.

Usefulness

The Patent Manual of Practice & Procedure (IP Australia, 2017) does not offer explicit guidelines on how to assess whether the proposed invention is able to be made or used in an industry. This omission implies that the criterion of usefulness is secondary to that of novelty and inventive step. The absence of explicit guidelines on assessment of usefulness may be explained by challenges in predicting what technologies and materials will be available in the future. A proposed product may be very difficult to make using the existing materials and technologies, but just in a near future some new materials and equipment may make its manufacturing simple. An expert in the field, assessing such proposal is likely to say: "It may be possible!"

After a short analysis of patentability it can be concluded that in order to be considered as a patent, a solution needs to solve an open-ended problem, must not be known before, must not be obvious to an expert in the technological field of the invention and must be evaluated by the expert as 'possible'.

Patent authorship and creativity

The majority of legal cases on inventorship that were considered in Australia and USA specifically focused on the individual contribution to the inventive concept. In order to establish the authorship of the invention, the judges have normally tried to establish who really conceived the idea that underpins the invention. The legal case of Townsend v. Smith ("Townsend v. Smith," CCPA 1930) is usually referred to for the definition of the conception:

> *"The conception of the invention consists in the complete performance of the mental part of the inventive act. All that remains to be accomplished in order to perfect the act or instrument belongs to the department of construction, not invention. It is therefore the formation in the mind of the inventor of a definite and permanent idea of the complete and operative invention as it is thereafter to be applied in practice that constitutes an available conception within the meaning of the patent law."*

In essence, legal practitioners consider authorship as mental act of idea generation. In other words, this legal definition of patent authorship nominates human ability to generate novel ideas (i.e. divergent thinking) as the major skill of engineering creativity. This means that the definition of engineering creativity needs to be closely related to human ability of generating ideas. Consequently, instruments of creativity measurement in engineering have to assess the skill of divergent thinking (i.e. idea generation), and not to devote much attention to evaluation of the convergent thinking skill.

Defining engineering creativity

Let us combine the findings from considerations of patentability and authorship. First of all, analysis of authorship established that a creator of an invention is a person that originally developed the idea for the invention. This implies that creativity is a human **ability** to generate solution ideas. Secondly, as per criteria of patentability, the idea needs to solve an open-ended problem, be novel, not obvious to an expert and accepted by her as possible. Consequently, engineering creativity can be defined as:

> *Engineering creativity is the **ability** to generate novel solution ideas for open-ended problems, ideas that are not obvious to experts in a particular engineering discipline and that are considered by them as potentially useful.*

Interestingly, this definition of engineering creativity can be viewed as expansion and clarification of the definition given by Harris nearly 60 years ago:

> *"the **ability** to produce a number of original ideas when confronted with problematic situation"* (Harris, 1960, p. 254).

How to measure engineering creativity?

The definition of creativity proposed by this study can be subdivided into the following three parts that can guide the design of an appropriate measurement instrument: (1) it is an ability to generate novel ideas to solve an open-ended problem, the ideas that are (2) non-obvious to an expert in the domain and (3) can be implement (today or in the future).

Ideally, an instrument to measure engineering creativity needs to assess all three parts of the creativity definition. Practically such assessment would not be realistic. Evaluation of novelty (1) would require thorough patent/publications search. Assessment of the other two parts would require engagement of experts. A pragmatic approach that can be implemented by university academics without massive investment of time and money may look similar to that used by Owens *et al.* (1957) in their PSA test or by Belski *et al.* (2015) to assess student idea generation performance.

Subjects are to be asked to record as many ideas as they can for an open-ended problem, which can be understood by them reasonably well (e.g. a problem that requires only basic knowledge of science to comprehend). The subjects' performance can be evaluated using the criteria that have been validated by Owens *et al.* (1957) and Harris (1960) as specifically suiting the engineering profession. These criteria are: (i) the number of independent ideas proposed by the subject (Fluency) and (ii) the Flexibility of these ideas. Counting the number of independent ideas seems straightforward. A measure of Flexibility is more challenging to decide upon. It is possible that the eight dimensions of MATCEMIB used by Belski *et al.* (2015) is the most suitable means to 'count' Flexibility. These eight dimensions practically cover most of the professional fields within the engineering domain, so ideas can be adequately classified. Accepting the MATCEMIB dimensions as the Flexibility measure can also eliminate the need to define sets of idea categories for every problem offered to subjects in order to assess their creativity. This will ascertain achieving higher inter-rater reliability of creativity assessments. The eight dimensions of MATCEMIB are clearly defined and would mean the same to an engineer from any part of the world. Also, the number of dimensions (breadth) seems to adequately evaluate the non-obvious nature of a solution. The higher the breadth of the proposed ideas, the broader are the operational principles that these solution ideas utilise. Expecting that an expert in any engineering domain holds expertise in two to three of the eight dimensions of MATCEMIB, the breadth of the ideas proposed by a subject would be a clear measure of whether the ideas proposed are non-obvious.

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Future-proof Engineers with Transformative Calibres

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CONTEXT Inadequate preparation of Engineering students for the 21st-century workplace is becoming a lightning rod for criticism. While STEM skills are set to underpin most of the emerging occupations, decades of efforts to re-engineer tech-based curricula seem to have made little headway in enhancing graduate employability. To date, studies contrasting different stakeholders' views on the essential capabilities of graduate engineers have largely settled on leveraging generic skills in technical curricula. Yet the gap remains wide between academic training and the evolving engineering profession. It is questionable if the incorporation of generic transferable skills into discipline-learning alone is sufficient to produce engineers for the future.

PURPOSE This study aims to provide new and structured insights into focuses of Engineering students and employers/industry stakeholders on career/employability development.

APPROACH This study adopts a framework approach to re-calibrate the professional preparation agenda. The Career Information Literacy Learning Framework (CILLF) is a framework created with STEM academics' inputs. It provides a mechanism to generate differentiators of focuses on career/employability development between Engineering students and employers/industry stakeholders. The Career Information Literacy (CIL) survey was conducted with final year Engineering capstone unit students (n=63, response rate 64%) at a STEM faculty in an Australian university (n=517, response rate 44%). A parallel, concurrent CIL survey with STEM employers targeting these students was conducted (n=62, response rate 78%). CIL profiles between student cohorts and between students and employers were compared.

RESULTS Profile analysis and Hotelling's T^2 test revealed no significant focal difference between final year Engineering capstone unit students and their STEM peers. However, significant difference existed between the Engineer student cohort and their potential STEM employers in focuses on career/employability development. Further Wilcoxon Rank Sum Test highlighted that Employers distinguish generic (cross-discipline), situated (discipline-specific) and transformative (trans-discipline) aspects of career/employability development, with the transformative aspect being most the prominent and desirable. However, such emphases were not discernible by the Engineering students.

CONCLUSIONS The CIL analysis uncovers that transformative capabilities are highly desired by STEM employers but remain largely under-detected by Engineering students. This discovery broadens the previously limited notion of adding generic skills to discipline-based learning to arrive at satisfactory professional preparation of future engineers. It also opens up a new line of inquiry into constituents of transformative capabilities.

KEYWORDS Engineering education, STEM employability, Career information literacy, Capstone units

Introduction

Inadequate preparation of Engineering students for the 21st-century workplace is becoming a lightning rod for criticism. While STEM skills are set to underpin most of the emerging occupations, decades of efforts to re-engineer tech-based curricula seem to have made little headway in enhancing graduate employability. To date, plenty of studies contrasting different stakeholders' views on the essential capabilities of graduate engineers have largely settled on leveraging lists of "additional" skills in technical curricula. Yet the gap remains wide between academic training and the evolving engineering profession. It is questionable if the mere incorporation of generic, transferable skills into discipline-learning is sufficient to produce engineers for the future.

We contend that, fundamentally, it is problematic to conflate employability development with *lists* of additional skills. Lists often lead to the production of itemised attributes which can be too generic for specific cohort needs, or too prescriptive to be applied across different programs of study. Conceptually, lists are also limited in their ability to show complex relationships between concepts. Such skills lists may be even less effective in the context of the engineering discipline given its multi-disciplinary and multi-faceted nature.

To capture the interrelated elements in career and employability development, we need a relational, structural thinking model with contextuality of fundamental learning, career development and discipline approaches. This model can serve as a tool to measure elements of career and employability development in higher education.

Purpose

This study adopts a framework approach as a way to re-calibrate the professional preparation agenda. It aims to provide new and structured insights into focuses of Engineering students and employers/industry stakeholders on career/employability development. To this end, we refer to the Career Information Literacy Learning Framework (Lin-Stephens et al., 2017, Figure 1).

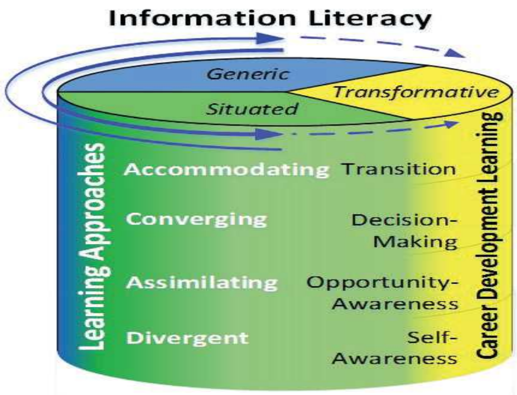

Figure 1: The Career Information Literacy Learning Framework (Version 2.0) (Lin-Stephens et al., 2017)

The Career Information Literacy Learning Framework (CILLF) (Lin-Stephens et al., 2016, 2017) unites three key theoretical frameworks in learning and teaching to form one conceptual device to gauge career and employability development in the context of higher education learning. It integrates models of Kolb and Kolb's (2015) learning approaches, Watts' (2006) career development learning, and Lupton's (2008) information literacy into a single framework which juxtaposes elements of Generic (cross-discipline), Situated (discipline-specific), and Transformative (trans-discipline) learning.

Following successful validation of the framework with data from academics, employers and students (Lin-Stephens et al., 2016, 2017), the CILLF is used here to delineate the relationship between several key aspects of university learning, which are by nature discipline-based, generic, transformative or career development related. In addition, we aim to use the CILLF to capture students' and employers' varying focuses on these aspects.

Approach

Applying the Career Information Literacy Learning Framework

The CILLF is a framework created with STEM academics' inputs. It provides a mechanism with differentiators of focuses on career/employability development between Engineering students and employers/industry stakeholders. By identifying these focuses, we can detect whether differences exist between student cohorts, and between students and employers.

Based on the CILLF, Career Information Literacy (CIL) survey instruments were developed. The CIL survey contains the CILLF attributes (Table 1.) with choice items coded according to these attributes (Table 2). The CIL survey provides a structural way for students to gauge their focuses on career and employability development, and for employers to discern key selection requirements of their ideal candidates to hire. We can then compare the CIL profiles between student cohorts as well as between students and employers.

Table 1: CILLF coding reference

Learning Approaches	***Career Development Learning***	***Information Literacy***		
		Generic	Situated	Transformative
Diverging	Self Awareness	***DSG***	***DSS***	***DST***
Assimilating	Opportunity Awareness	***AOG***	***AOS***	***AOT***
Converging	Decision Making	***CDG***	***CDS***	***CDT***
Accommodating	Transition Learning	***ATG***	***ATS***	***ATT***

We pose two research questions to understand Engineering students' focuses on career and employability development.

RQ1: Does the Engineering student cohort share the same focuses on career and employability development as their STEM peers?

RQ2: Does the Engineering student cohort chare the same focuses on career and employability development as their STEM employers?

Data collection

The Career Information Literacy (CIL) survey was administered to 34 final year capstone unit students at a STEM faculty in an Australian university. The survey was administered at the end of semesters face to face. This paper reports findings from the Engineering student cohort. A parallel, concurrent CIL survey was conducted with STEM employers who approached this faculty via the Career and Employment Service to recruit STEM students.

Data analysis

Profile analysis and Hotelling's T^2 test were deployed to analyse the similarity of score profiles between cohorts. Two hypotheses were tested to check the significance of different patterns- Parallelism and Coincidence. In addition, Wilcoxon Rank Sum Test was used to determine differences between Generic, Situated, and Transformative learning.

Table 2. Questions 1& 2 for Students and Employers/Industry Stakeholders

QN	Students	Employers/Industry Stakeholders	Code
Q1	**How important are the following to you for your next career move?**	**What do you value in a candidate?**	
1.1	Understanding your own interest, skills values, strengths, etc.	Their self-understanding of interests, skills, values, strengths, etc.	DSG
1.2	Your discipline-based knowledge, skills and approaches	Their discipline-based knowledge, skills and approaches	DSS
1.3	Ability to critically reflect on your motivation and behaviour in making career transitions	Critical reflective ability on one's motivation and behaviour in making career transitions	DST
1.4	Knowledge of broad career options	Knowledge of broad career options	AOG
1.5	Knowledge of specific work opportunities & industry requirements to which your disciplinary learning would be an asset	Knowledge of specific work opportunities & industry requirements to which their disciplinary learning would be an asset	AOS
1.6	Motivation and knowing how to contribute to any work in a meaningful way	Motivation and knowing how to contribute to any work in a meaningful way	AOT
1.7	Ability to evaluate your preferred career choices	Ability evaluate one's preferred career choices	CDG
1.8	Ability to target specific jobs, based on relevance of your personal profile, learning, experiences and circumstances	Ability to target specific work, based on relevance of one's personal profile, learning, experiences, and circumstances	CDS
1.9	Ability to think outside of the box in career decision making	Ability to think outside of the box in career decision making	CDT
1.10	Sound skills to handle job application & recruitment process	Sound skills to handle job application & recruitment process	ATG
1.11	Ability to effectively show how you can add value to an employing organisation based on who you are and what you study	Ability to effectively show how one can add value to an employing organisation based on who they are and what they study	ATS
1.12	Ability to challenge your existing practices and take critical actions to adapt to changing environments	Ability to challenge one's existing practices and take critical actions to adapt to changing environments	ATT
1.13	Other (please specify):	Other (please specify):	
Q2	**What contributes to your employability?**	**What influences your hiring decisions?**	
2.1	Degree relevance & specific skills	Degree relevance & specific skills	
2.2	Generic/transferable skills evidenced in a range of activities (work experience, extracurricular activities, volunteering, etc.)	Generic/transferable skills evidenced in a range of activities (work experience, extracurricular activities, volunteering, etc.)	
2.3	Application quality and interview performance	Application quality and interview performance	
2.4	Prior contact with employers through work-integrated programs, internships, networking, volunteering, paid and unpaid work, etc.	Prior contact with candidates through work-integrated programs, internships, networking, volunteering, paid and unpaid work, etc.	
2.5	Referral/recommendation	Referral/recommendation	
2.6	Other (please specify):	Other (please specify):	

Results

Demographic and activity-based features of the Engineering student cohort and the whole of STEM faculty's cohort are summarised in Table 3. The Cronbach's alpha value for the Engineering cohort is 0.90, giving us confidence of the robustness of estimates derived from the statistical tests. The Engineering student cohorts' response rate is also very high (64%).

Table 3. CIL survey capstone unit student respondents' characteristics (Engineering cohort vs Whole of STEM faculty cohort)

	Engineering cohort	STEM whole faculty
Total number of responses (n)	63	517
Total number of enrolment (N)	98	1176
Response rate	64%	44%
Male	89%	67%
Female	8%	32%
Age		
19 or under	0%	0.4%
20-25	81%	81%
26-30	13%	10%
31-40	3%	6%
41+	3%	3%
Activities in the past 12 months		
Part time work	68%	75%
Job search	48%	49%
Unpaid work experience	40%	28%
Student groups/societies	33%	28%
Volunteer or community work	19%	30%
Full-time work	17%	11%
Project work involving external clients	13%	21%
Professional association involvement & networks	11%	8%
Overseas exchanges or studies	8%	6%
Average total paid work history	3 years 1 months	4 years 2 months
Average total unpaid work history	3 months	10 months
Plan within 1 year of completing degree		
Work	86%	73%
Further study	24%	37%
Other	3%	10%

Table 4 outlines the STEM employer/industry stakeholder respondents' characteristics. (n=62, N=80, response rate 78%).

Table 4. CIL STEM Employer/Industry Stakeholder Survey Respondent Characteristics

	Frequency	Percentage
Organisation type		
Large enterprise (200+)	28	46%
Small/Medium Enterprise (< 200)	25	41%
Government	5	8%
Not for profit	4	7%
Male	24	39%
Female	38	62%
	Length of time	
Average experience in workforce	13 years 3 months	
Average experience in hiring	7 years 5 months	

Profile analysis illustrates the similarity and difference of score profiles between cohorts. Following this, Hotelling's T² test detects parallelism and coincidence of the score profiles to establish if differences are significant.

Parallelism: Cohorts are concluded as different in their focuses on career and employability development if their CIL profiles are not parallel, i.e. they exhibit incongruent scores across key measurements.

Coincidence: If the cohorts' profiles are parallel between variables, we test further to see if the cohorts' scores are at equal levels across variables. Cohorts are concluded to have different profiles if they do not have the same value for each measurement (non-coincidental).

As we can see from Figure 2 and 3, the Engineering student cohort's CIL profiles does not present significant difference from their STEM peers for both Q1 (CIL questions) and Q2 (supplementary questions). Please note that the data points in Figure 2-5 are connected to assist visibility; therefore, the lines do not represent trends.

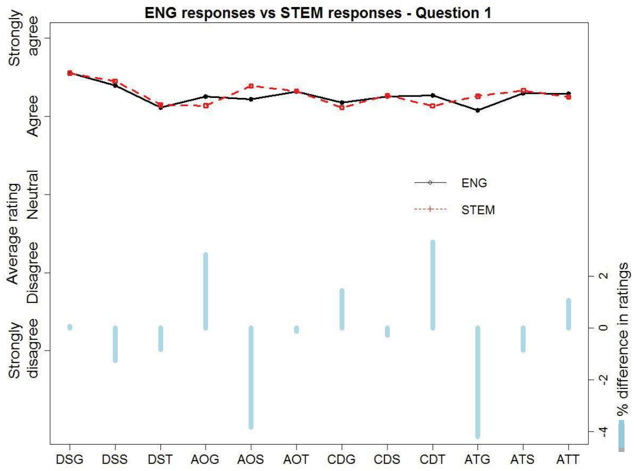

Figure 2. Q1 Responses
Engineering Cohort vs. Other STEM Peers

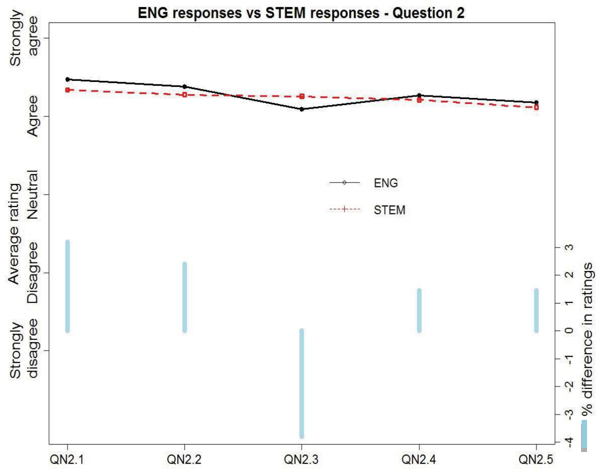

Figure 3. Q2 Responses
Engineering Cohort vs. Other STEM Peers

Hotelling's T² (Table 5 and Table 6) confirmed that there is no statistically significant difference between the Engineering student cohort and their STEM peers.

For RQ1, therefore, we conclude that there is no intra-cohort difference between Engineering students and other STEM students in their focus on career and employability development.

Table 5. Hotelling's T² Test Results Q1
Engineering Cohort vs. Other STEM Peers

Hypothesis	Hotelling's T²	Critical Value	P-value
Parallel	13.57	20.277	0.48
Coincident	0.026	3.86	1.00

Table 6. Hotelling's T² Test Results Q2
Engineering Cohort vs. Other STEM Peers

Hypothesis	Hotelling's T²	Critical Value	P-value
Parallel	7.17	9.61	0.21
Coincident	0.336	3.86	1.00

However, for RQ2, profile analysis and Hotelling's T² test revealed significant differences in focuses on career/employability development between final year Engineering capstone unit students and their potential employers.

Figure 4 and 5 show the very different CIL profiles between Engineering student respondents and their STEM employers.

Hotelling's T² (Table 7 and Table 8) confirmed the CIL profile difference between the Engineering student cohort and STEM employers to be significant.

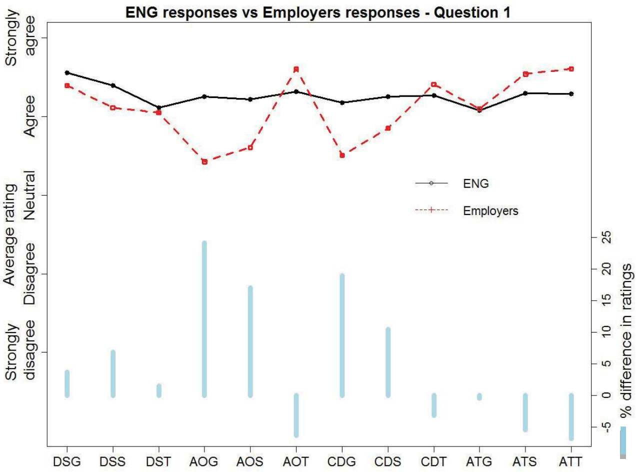

Figure 4. Q1 Responses
Engineering Cohort vs. STEM Employers

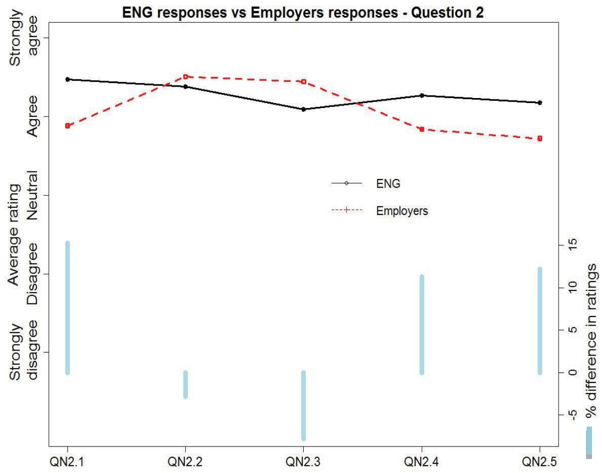

Figure 5. Q2 Responses
Engineering Cohort vs. STEM Employers

Table 7. Hotelling's T² Test Results Q1
Engineering Cohort vs. STEM Employers

Hypothesis	Hotelling's T²	Critical Value	P-value
Parallel	104.72	22.99	1.37E-10

Table 8. Hotelling's T² Test Results Q2
Engineering Cohort vs. STEM Employers

Hypothesis	Hotelling's T²	Critical Value	P-value
Parallel	46.22	10.04	3.05033E-07

Wilcoxon Rank Sum Test was used to investigate the differences further. The CIL scores of the Engineering student cohort's (Table 9) and STEM employers (Table 10) were compared to determine differences between focuses on Generic (cross-discipline), Situated (discipline-specific) and Transformative (trans-discipline) learning.

Table 9. CILLF Profile of Engineering Students

Learning Approaches	*Career Development Learning*	*Information Literacy* Generic	Situated	Transformative
Diverging	Self Awareness	*DSG 4.80*	*DSS 4.76*	*DST 4.50*
Assimilating	Opportunity Awareness	*AOG 4.24*	*AOS 4.57*	*AOT 4.50*
Converging	Decision Making	*CDG 4.26*	*CDS 4.35*	*CDT 4.20*
Accommodating	Transition Learning	*ATG 4.29*	*ATS 4.28*	*ATT 4.54*
	Average	*4.40*	*4.50*	*4.44*

Table 10. CILLF Profile of STEM Employers/Industry Stakeholders

Learning Approaches	*Career Development Learning*	*Information Literacy* Generic	Situated	Transformative
Diverging	Self Awareness	*DSG 4.39*	*DSS 4.11*	*DST 4.05*
Assimilating	Opportunity Awareness	*AOG 3.43*	*AOS 3.61*	*AOT 4.61*
Converging	Decision Making	*CDG 3.51*	*CDS 3.85*	*CDT 4.41*
Accommodating	Transition Learning	*ATG 4.10*	*ATS 4.54*	*ATT 4.61*
	Average	*3.86*	*4.03*	*4.42*

Although there seemed to be a higher focus of the Engineering cohort on Situated (discipline-specific) learning, the Wilcoxon Rank Sum Test did not confirm a statistical significance with this sample (Table 11). However, the test (Table 12) showed that Employers distinguished between Generic, Situated and Transformative aspects of career/employability development learning, with Transformative learning being the most prominent and desirable. In contrast, such emphases were not clearly discernible by the Engineering students.

Table 11. Wilcoxon Rank Sum Test Results (Engineering student)

Intra-category comparison p-values matrix	*Average scores*	*Career Information Literacy*		
		Generic	Situated	Transformative
Generic	*4.27*	-	*0.739*	*0.684*
Situated	*4.29*	-	-	*0.045*
Transformative	*4.24*	-	-	-

Table 12. Wilcoxon Rank Sum Test Results (STEM employers)

Intra-category comparison p-value matrix	*Average scores*	*Career Information Literacy*		
		Generic	Situated	**Transformative**
Generic	*3.86*	-	*0.013*	***<0.001***
Situated	*4.03*	-	-	***<0.001***
Transformative	***4.42***	**-**	**-**	-

Conclusions

The study successfully demonstrated a structural approach to understanding the STEM professional preparation from cross-discipline, discipline-specific and transformative aspects.

The CIL analysis uncovers that transformative capabilities are highly desired by STEM employers but remain under-detected by Engineering students. This discovery broadens the previously limited notion of adding generic skills to discipline-based learning to arrive at satisfactory professional preparation of future engineers. Further work on 'transformatives' is crucial. Equally interesting is that Engineering students did not differ significantly from their STEM peers in their focuses on employability and career development, given that the Engineering discipline has distinct professional accreditation requirements and is often viewed as embodying more vocational orientation than the rest of the STEM cohorts.

We acknowledge potential limitations to this study. Due to the sample size, the engineering students were analysed as a cohort; therefore, no separate analysis was done for sub-fields of engineering. In addition, the STEM employer sample is drawn from employers who approached the STEM faculty to recruit students; therefore, may not be representative of all STEM employers. Furthermore, the study was conducted in one institution only. Replication of the study in other institutions may provide further insights into STEM employability.

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A new, common, experiential 'Engineering Practice' course

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SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT Throughout 2015 and 2016, the faculty of Engineering and Build Environment at the University of Newcastle re-envisaged the suite of engineering programs on offer to meet the future needs of students and society. One of the key areas addressed in these changes was to form a strong backbone of, our so called, professional practice courses running vertically through the programs. The foundation of this professional practice stream is 'ENGG1500 – Introduction to Engineering Practice'. This paper describes the implementation of this PBL course, the pitfalls and successes in the first offering of this new course.

PURPOSE This paper is to inform the engineering education community of our development of a new experiential learning first year course, and to provide details of the projects used for others considering the implementation of a project based introductory course. The ENGG1500 course aimed to give first year students an 'engineering experience' building excitement and thus increased engagement within their chosen degree, and contextualising the technical knowledge gained throughout the early stages of their program.

APPROACH The course was created as a common first year – first semester subject for all engineering students and was comprised of global lectures with discipline specific workshops. The workshops were the focus of this course, in which students completed a project, starting from an open question through to testing of a complete solution. Workshops predominantly operated as flipped classrooms encouraging students to work independently. The lectures were supplementary, containing information such as communication skills, problem solving and guest lectures from industry partners, to assist students with their projects and support technical learning in other subjects.

RESULTS The first offering of the course has been evaluated based upon formal and informal student feedback, attendance and student enthusiasm. Discipline specific projects, with interactive goals, generally produced high levels of engagement reflected by very high attendance in workshops. Some projects needed their difficulty increased as students requested additional work to do outside of scheduled class. Interestingly the lowest engagement was in the project using the most expensive and technologically advanced equipment; e.g. augmented reality. The engagement level of staff was seen to directly correlate with the success of the course, and senior students leaders provided strong engagement. Non-technical skills such as communication and teamwork were given relevance by relating them to the current projects, however the variations in projects lead to some discipline student groups feeling neglected when their project did not specifically relate to the lecture material.

CONCLUSIONS Semester long project based learning is an effective tool for building an engaging first year engineering course. Tangible projects and invested staff are required this process to be successful. Above a threshold, monetary investment into project equipment does not appear to correlate with student engagement.

KEYWORDS

Experiential learning, first year engineering, PBL

Introduction

This paper discusses the development, first delivery, and initial outcomes of a project based learning course, designed to build engagement in the University of Newcastle (UoN) engineering degrees. Whilst not a novel concept in engineering education, this paper is intended to add additional learning objects (projects) to the public domain and report on the personal learnings achieved in the development and deployment of this course.

This course was developed as part of the reimagined engineering programs commencing their roll out from Semester 1, 2017. These eight new engineering programs were centred around the aspiration of a degree “for their world not ours” and involved completely rebuilding many of our courses which had traditional teaching styles and content, and replacing them with new courses which embraced novel learning techniques appropriate for the new world engineer. One aspect of the new programs was the creation of 4 cohesive, core, ‘Professional Practice’ courses as a vertical spine throughout the degree programs. These 4 courses replaced the existing Introduction to Engineering Practice, Applied Ethics, Engineering project Management. These new Introduction to Professional Practice, Sustainable Engineering Practice, Managing engineering Projects and Engineering Complexity courses were designed as completely new courses with no material carry over from the predecessors.

The University of Newcastle’s pre-2017 engineering programs used a common ‘GENG1803 - Introduction to Engineering Practice’ course which was introduced in 2005. Originally located in semester 2, it was moved to semester 1 due to pedagogical needs associated with other technical courses in 2009, however its curriculum was not substantially updated to reflect the inherent change in student capability. The intent of GENG1803 was to introduce students to the engineering degree as a whole, contextualise the knowledge they learn in other subjects, and teach non-technical skills such as communication. This was originally achieved, in part, through the Engineers Without Borders (EWB) challenge. Though in recent years custom in house projects became normal. Student feedback for GENG1803 often performed less than ideally. One common complaint of the students centred on a dislike of, or far more commonly a disinterest in, the projects.

We herein present knowledge gained from our new first year Introduction to Profession Practice course, ENGG1500 to aid others pursuing a similar endeavour. Simply put the course was designed to build engagement with the students. To achieve this we selected and created projects for a project/problem based learning (PBL) delivery model. We utilised a single, semester long, student project to drive learning rather than dictating learning through lecture delivered material. To be successful in this form, we argue that it is important that the problem needs to be complex enough to keep students working throughout the entire semester, yet approachable enough for students, at least in part, to control the way in which they solve the problem.

While PBL had been shown to be successful at many other institutions it was a relatively underutilised teaching method at the University of Newcastle in the Engineering schools, especially in the general units. Preliminary discussion and research into PBL were frustrated by a lack of applicable information to the specific intents for our first year engineering course at the University of Newcastle. Contradictory opinions were common amongst staff contacted at our Centre for Teaching and Learning, other academics contacted across Australia, and Teaching practices known to be effective within our own school. Additionally, the reported successful practices of others often appeared impractical in the context of ENGG1500. The common exemplar being Olin College, who run an incredibly successful PBL engineering degree for very top academic students in the United States, and we anticipate on a far larger budget than the University of Newcastle was able to provide. Other examples such as the University of Illinois at Urbana-Champaign with a much smaller budget and more diverse student body, are more applicable but still not, in our view, directly translatable. During initial development work, an external education consultant was engaged. However they were released as it became clear the development needed in-house experience and commitment. Although there is considerable research available on PBL, distilling relevant information became critical. Our overall assessment from the literature, discussions and early development work lead us to conclude that this course would be custom built and tailored to the specific university to work most effectively.

The University of Newcastle has several identifying traits. 34% of our student are low socioeconomic status, many students are their first in family to attend a university and, Newcastle has a strong mining and industry backbone. The University of Newcastle has approximately 40 000 students with the 2017 intake into the new engineering program being just over 400 students. The engineering programs at Newcastle have historically performed well across many metrics.

Development

As part of the development phase, we engaged with students across our engineering facility to gain their collective insight. A voluntary, hard copy, 4-page survey was created, with long answer questions directly related to the previous GENG1803 course and a series of Yes/No questions (with optional comment areas) related to topics that might be included in the new course. The survey was deployed within a second semester first year course (for a reactive response from students that had 'just' completed GENG1803), and a third year course (to gain a more reflective perspective). A return rate of ~85% was obtained indicative of a strongly engaged student group. The results from the Yes/No questions of the first year students are displayed in Figure 1 where the ratios of Yes: No are plotted. There is an overwhelming number of ratios greater than 1, all but the lowest 3. The strong desire to learn the so called "soft skills" was exemplified by an overwhelming desire from students to be taught report writing, despite report writing courses historically receiving poor student feedback. This information was used in the initial stages to dispel some of the assumptions of our academics surrounding the course content. It is important to recognise that this is student opinion data only, and was not the only metric used for designing the course. It served to highlight that "soft skills" are not inherently disliked topics but the way in which they are presented is critical for student engagement.

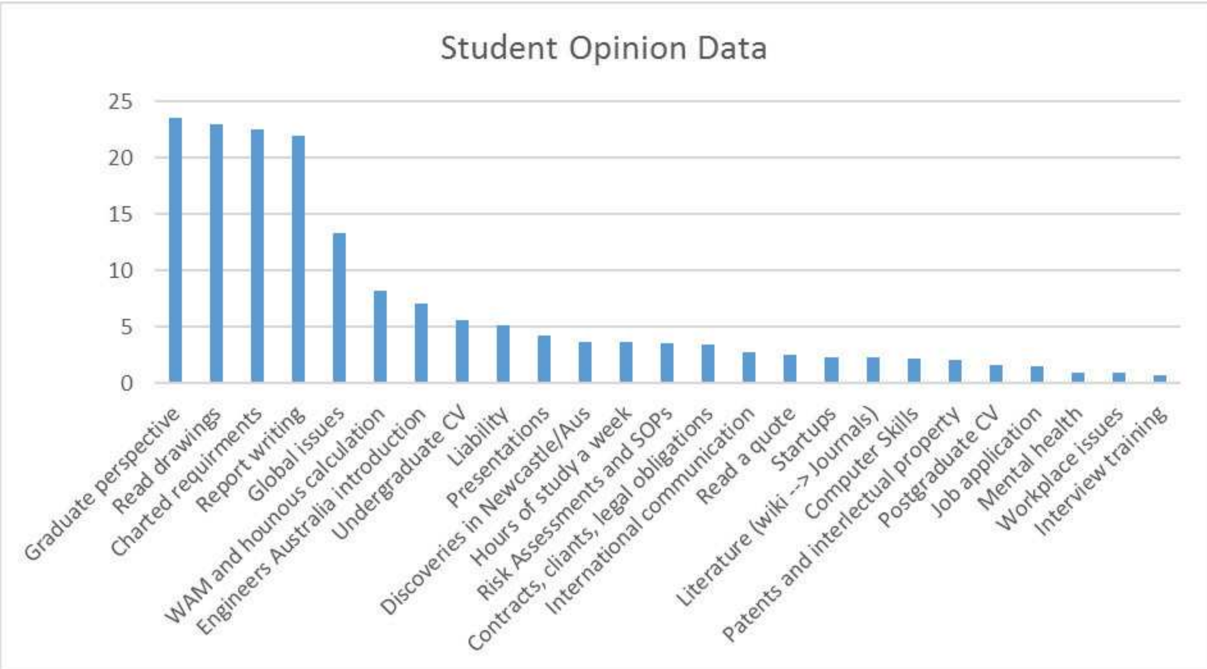

FIGURE 1 Collation of 1st year student input illustrating what they rated highly, and what they were less interested in.

Structure

ENGG1500 was designed and timetabled with the focus on a 2 hour discipline specific project based workshop session, supplemented by a common lecture session and an unstaffed tutorial each week. Student completed their projects during the workshop sessions and these classes were controlled and taught by individual disciplines. In some weeks, the workshop time was utilised as project specific lectures by the supporting staff, other weeks as tutorial time, with the remainder as open time for students to work on their projects: most disciplines used different styles throughout the year as the individual projects demanded.

The unstaffed tutorials were simply created as an empty a timeslot in the student's timetable. It was intended that students would work on their reports with the objective that this would reduce students 'leaving it to the last minute'. This aspect did not work, and was not appreciated by the student body as was indicated in the student's qualitative feedback.

Project development

The majority of the development work was centred on creating an engaging and relevant project for the students. We anchored the project as the cornerstone of the course and the key aspect for each project was an interactive outcome. That is, something that the student teams could demonstrate on test day and show to friends and family at the end of the course. Six disciple specific projects ran simultaneously throughout the course, summarised in Table 1. Interestingly the Electrical and Mechatronics projects, developed separately, independently converged on similar outcomes, and were eventually coalesced.

Projects were generally designed in close contact with, or by, discipline specific experts. We identified a suitable expert within each discipline, and engaged them with a brief for the collaborative design of a suitable project and worked closely with the course co-ordinator to produce a project that was based on core discipline knowledge.

Three of the six projects were co-developed by senior undergraduate students over the preceding summer break, with support from a staff member. This process proved remarkably successful as these senior undergraduate students were highly motivated and focused. These students also provided curriculum scaffold information relevant to their field of study as they were still actively undertaking their studies.

The Micro Wind Turbine project was designed by PhD students from the University of Newcastle's mechanical engineering wind turbine research group. These PhD students showed a similar enthusiasm towards teaching to the other senior undergraduates and their expert knowledge enabled them to develop appropriate course content for first year students in the relatively complex field of fluid dynamics. A large 'value add' for this mechanical project was student access to various wind turbine assemblies that the group has created and actively use for their research. This PhD inspired project, ensured that the students had a tangible real-world application in view, preventing the project from appearing like 'a high school project'. A competition emerged on the testing day to see which undergraduate groups could get closest to the PhD exemplar turbines.

By way of contrast, some disciplines were unable to identify suitable 'summer students' and academics were unable to commit the required time for good project development. This resulted in these projects being created and led by the course coordinator, who did not have a background in these disciplines. As a result these projects lacked the strength of the disciple connection observed in the other projects. The staff tasked to run these workshops demonstrated no ownership of the content, which was apparent to both students and other staff. These projects created the largest (and disproportionate) workload for the course coordinator throughout the semester, with the additional efforts required to try and generate student engagement for these disciplines.

Table 1 Discipline specific projects used in ENGG1500

Project name	Key tasks covered	Disciplines
Micro Wind Turbine	Designed and build a micro wind turbines using a supplied generator and $100 budget.	Mechanical
Semi-Autonomous Vehicle	Assemble and program an Arduino controlled vehicle to navigate an obstacle course. Most hardware is supplied.	Electrical/ Mechatronics/ Computer systems
21st Century Lecture App	Created an app using MIT app inventor which allowed students to "check in" to lectures and interact with the lecturer.	Software
Solar Desalination	Convert salt (sea) water to drinkable water mainly using solar power with a $100 budget and 1 m^3 space.	Chemical
Water Tower	Design and build a 10:1 scale water tower, supporting 50 L of water 1.25 m above the ground with a $100 budget.	Civil
Augmented Reality Simulation	Design a river crossing by creating specific terrain (university grounds) in augmented reality and simulating flood conditions.	Surveying/ Environmental

Use of Global Lectures (in this PBL course)

A challenge resulting from the highly independent nature of each project was that it became impossible to provide global lecture material of immediate value to each project group. This pushed more emphasis on the workshop sessions to cover all project specific information. Global lecture material was therefore developed to provide interest and relevance, encouraging student attendance. No content in these sessions was directly assessable. Despite this challenge, it enabled material to be presented which ordinarily would not fit into a course. For example, engineering problem solving ethos, program honours calculation, creation of models and the implicit assumptions made, research topics of the university's academics and relationships between current courses and future course all became lecture content. This 'orientation' content was created partly from the aforementioned survey, partly from asking senior students "what do you wish someone told you in first year?", and from asking other academics "What (general knowledge) would you like your students knew before they came to your class?".

The global lecture material also initiated our planned program long written communication skills taught and reinforced throughout our Professional Practice stream. This initial introduction to technical writing focused on 'why we write' rather than 'how to write' with large focus on understanding the target audience, and how the audience will influence the writing style. Consequently the first ENGG1500 assessment task involved writing a report "for another ENGG1500 student from another discipline", and the second linked task was to proofread, edit, and grade 4 of those reports. Concepts such as concise wording and appropriate language were reinforced through exemplars of technical writing, in the form of research publications, PhD and Honours theses.

Physical Development challenges

The practical nature of the course required non-traditional learning spaces and a volume of physical hardware to be designed, constructed and/or commissioned. The lack of suitable space during the early developmental phase of the course greatly frustrated project design. Despite the University and Faculty having several discrete groups of support staff, all of which should have contributed to the development of the course, one disciplines team voluntarily took ownership of ENGG1500 and completed the work required to ensure timely delivery. Without that 'buy in' from that one technical group, the outcome for this course would have been severely compromised. As a learning outcome for academics planning to pursue this type of course development, ensuring that the technical/supporting staff have a complete understanding of the requirements and deadlines is critical. This was achieved by involving them in the planning and course design several months before the start of semester.

Delivery

As with the design of the projects, senior students also did a large proportion of the demonstrating, with academic mentoring and support through the course-coordinator as needed. Senior students managed three entire projects containing approximately 75% of the student cohort. We believe that these projects were all highly successful due to the positive attitude of these senior student demonstrators, towards both the specific project and the practice of education. As these students were involved during the development of the project they felt a strong sense of ownership and were heavily invested in its success. The first year students readily picked up the enthusiasm of the workshop leaders and carried it throughout the project. Senior students adapted well to the novel teaching strategies of problem based learning, encouraging students to drive the project forward, supporting and advising when needed.

This was in direct contrast to some of workshops run by full time academic staff which suffered from a distinct lack of engagement by both staff and students. This resulted in little imagination and creative thinking in the solutions that the students produced, undermining a main goal the course.

A large difficulty for the course coordinator was a lack of expertise across some discipline areas, which caused a heavily reliance on the workshop leaders. However keeping abreast of all projects was essential for the course as a whole to run smoothly. This led to effectively coordinating 6 separate disciple specific courses as well as the course as a whole. Unsurprisingly the hours required were excessive. During the initial and final weeks of the course over 15 hours of face to face time with students was common and test week required approximately 25 hours of face to face contact. Despite the taxing nature of so much face to face time, as well as maintaining an open door policy, it was felt essential to establish a strong rapport with the students for the course to succeed, and for the general success of the students. The workload is expected to decrease as the course matures, however it is believed this type of course will always be time intensive to run optimally.

Outcomes

The courses first offering was in semester 1 2017, and analysis of the course has been performed using formal student feedback, discussions with students and tutors as well as monitoring attendance and performance in workshops.

The formal Student feedback on course results are displayed in Figure 2. Overall the course performed well, with between good and very good levels of student satisfaction across most areas. The course performed relatively poorly in 'Organisation' partly due to the dynamic nature of assignment briefs and partly the fluid assessment due dates, mainly attributed to it being the first offering of the course. A single assignment outline was issued covering all projects, this caused some confusion as sections were not equally applicable to all disciplines and projects, as a result of this we believe that the 'Criteria and Expectations' metric in our student feedback suffered. This was corrected for the final assessment by having a general section, and then a discipline specific section. Due the open ended nature of the course, assessment tasks were intentionally kept broad to encourage creative thinking and prevent students working to a rubric. This resulted in some confusion, but greatly improved the creativity displayed in the projects and challenged the students to think independently.

As can be seen in Figure 2 Assessment Feedback was by far the lowest scoring category. This was largely due to a perceived extended time to return assessments in the Semi-Autonomous Vehicle project. A single marker was used for all autonomous vehicle submissions for homogeneity of grades and feedback. This marker needed to meet other time demands and whilst meeting the University policy target for the return of assessments, resulted in delayed feedback compared to the other project groups.

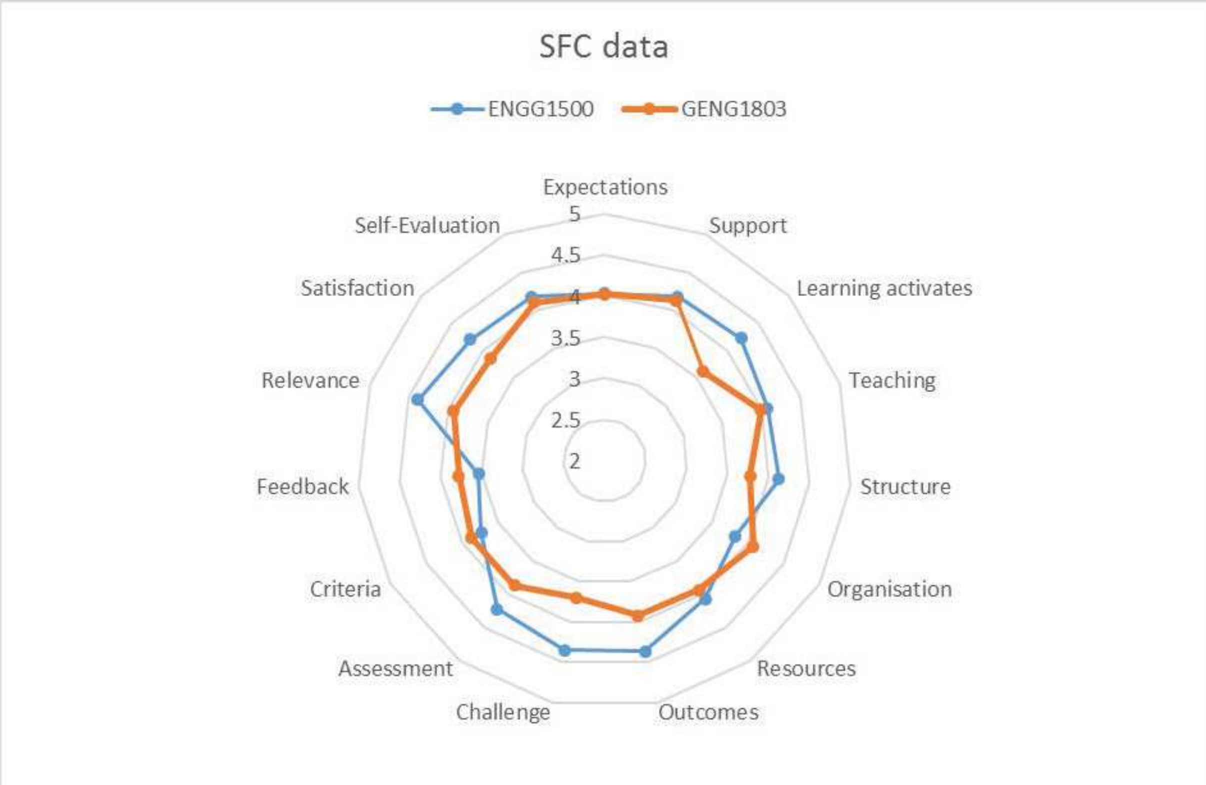

Figure 2 Student feedback on courses data

The numerical data itself is separable into student program codes enabling investigation into feedback from specific programs. Whilst overall this proved relatively unhelpful in identifying areas of improvement, it did allow for an interesting observation. In some cases, multiple program codes did exactly the same project, and so conceivable should have given identical feedback, however the data shows drastic differences. Three different programs groups, Electrical (in teach out), Electrical & Electronics, and Mechatronics all completed the Semi-Autonomous Vehicle project. Picking apart their student feedback numerical results demonstrated a maximum spread of 1.33 (i.e. 2.20 to 3.53) in the Feedback category. A better understanding of course performance was gained through face to face discussions with students and their comments within the Student feedback instrument.

Students lecture attendance remained high throughout the semester. Many students embraced the idea of seeing how other disciplines think whilst some were disinterested by the general nature of the lectures. Student comments generally attributed the lecture enjoyment to the positive attitude and presenting style of the lecturer rather than the specific content. The young age of the lecture (28) helped in empathising with the students, building trust and creating a positive atmosphere, however it did prevent this academic from speaking with authority on certain topics which require experience. To compensate guest lectures from experienced personal, though not necessarily academics, on; creative thinking, employability, life as an engineer, mental health and the role of OH&S were highly successful in keeping lectures interesting to the general cohort. Attendance in workshops was universally high, despite being them being ungraded. Most workshops achieved above 80% attendance most weeks and regularly 100%. Some projects, the Semi-Autonomous Vehicle project in particular, saw students regularly requesting more access to the workshop room to continue working on their projects outside of scheduled classes. Some teams progressed so far in advance of the original project description that the difficulty of the project was twice increased, to keep the motivated students challenged.

When considering overall student engagement and satisfaction there was no correlation to the expense of a project. The Augmented Reality project was the most expensive yet had the lowest engagement, whereas the tighter budget design and build projects ($100 per group of 4 students) performed well. No feedback was given implying spending more money would significantly improve the projects. That said, allocation of space, refurbishment of rooms and purchasing of general workshop equipment was critical for the course to run effectively. Our assessment is that it appears there is a minimum requirement to create a meaningful project, but above this minimum, diminishing returns are seen. A better return on investment is likely from hiring additional/better staff rather than into more elaborate equipment.

It is highly evident, that for a success implementation a committed champion for each project is required. It was also apparent that a custom project designed in house was an effective method of performing project based learning whereas adopting a project from elsewhere, led to lack of ownership. This was exemplified by the successful senior student created and lead projects vs the course co-ordinator designed augmented reality project.

'Test day' was critically important for student engagement and satisfaction. The vast majority of students were greatly excited by testing their finished products and evidently proud of their results. Students were driven to produce the best product they could with many additional workshops running in the final weeks to satisfy the extra time and effort the students wanted to apply. The final lecture (the week after 'testing week') was predominantly devoted to discussion and demonstration of projects. Videos and photos taken during test week were shown and the 21st Century Lecture App was actually deployed in the lecture. If measured by applause, this lecture appeared to generate the highest level of engagement of the whole course.

Resulting from teaching 'why' and not 'how' engineers write, saw an increase in student opinion on the importance of writing and a deeper understanding of the underlying principles. However, it also lead to some obviously poor writing practices. For example, heavy use of colloquial language and poor understanding of how to write an abstract perpetuated through the entire course. Some disciples saw the lack of teaching a formal writing style detract from the quality of the reports while others saw it improve. This is one area for reconsideration in 2018, both with the ENGG1500 curriculum, and the teaching staff associated with the course.

Whilst anecdotal, there appears to have been an apparent increase in total program retention in for students enrolled in ENGG1500 compared to the previous years retention data. Whilst small, and from a single measurement, the first semester program attritions reduced by 3%. At an individual course level, the withdrawal rate reduced by approximately 1/3 of the 'norm' for past offerings of GENG1803. These are currently simply correlations, without substantive direct data, and the decision for any student to remain in a degree is influenced by a great number of factors. However, it appears that this is a positive result for the course.

Observations, Intentions and Potential Improvements

We argue that in order for PBL to be fully utilised the projects needed to be open ended so that multiple solutions could be equally effective. This allowed for creative problem solving to truly flourish, opposed to the more prescribed 'standards-driven' design typical of later, more technical courses. However, unstructured workshops where students were given freedoms, lead to general confusion and inefficient workflow, especially in the first weeks of university. Students would often fixate on their first solution, and be unwilling to attempt anything new. Ironically projects which had a more structured initial stage, slowly encouraging students to become self-sufficient were more productive. Consequently the second iteration of the course may structure the first 4 weeks and have a small assessment in week 5. Completing this initial assessment task should develop the skills the students need to approach the bigger problem, generate confidence and lead to more creative solutions.

The unstaffed tutorial times did not have their desired effect, as they were not linked to the rest of the course. This was due a timetable issue that could not be resolved before enrolments opened. Restructuring of the tutorial times into open help session available to all student but staffed by discipline specific workshop leaders will be trialled in 2018 as a way of giving students more time to ask questions and receive feedback on their assessments.

Some of the earlier assessments will be rewritten in a format similar to the final assessment, with each having a general section and a discipline specific section. This is intended to remove some of the confusion for students, and allow the disciplines to better prepare their own students for what will be required of them in their reports for future courses. It is also evident that a considerably larger allocation of marking hours is required to improve the written feedback on reports.

The technical writing aspect of the course, while not poorly received, was insufficient. More time and focus needs to be placed on this area. It is intended that more lecture time will be spent on this, and it is also possible that each workshop will spend a session discussing discipline specific writing styles and providing feedback on reports.

Some staff will be replaced in the projects which suffered from poor staff engagement. It was obvious that staff need to be involved with the course many months prior to its start date. Initial meetings with new staff are happening approximately 6 months before the course will run again. Senior students will be investigated to be part of all projects.

2018 will see the introduction of the new Medical engineering degree at the University of Newcastle, and the new discipline will require its own project. This presents a unique problem in the complete absence of any current Medical engineering staff or students.

Conclusions

The University of Newcastle offered a new general first-year, problem based learning course in 2017. Student engagement and satisfaction was greatly increased over the previous introductory course.

Discipline specific tangible projects that were assessed on ‘Test Day’ in the second last week of semester proved crucial to the positive outcome of the course.

Workshop staff were instrumental in both course development and delivery of projects, with undergraduate and postgraduate students completing the majority of the work with excellent results.

Lectures became secondary in importance to workshops and careful attention was required to keep them interesting to maintain attendance.

Students enrolled in similar programs, completing the same project, receiving assignment feedback from one common marker, at the same point in time, provided statistically significant different student feedback scores on the student feedback of courses, ‘assessment’ scale. This suggests that investigating the difference between different discipline projects numerical variance in their qualitative student feedback, is likely to be heavily confounded.

Understanding Student Engineers Perceptions of Their Own Capacity for Thinking Creatively and Analysing Problems

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SESSION C3: Integration of teaching and research in the engineering training process

CONTEXT Insight into student understanding of their own learning is a key element in being able to design and implement effective approaches in student-centred learning. In this paper we examine the findings of a preliminary study into student perceptions of their own capacity for thinking creatively and analysing problems. This study serves as a pilot to a larger joint University study between Queens University, Canada and The University of Adelaide, Australia involving engineering-design students. Results of the pilot study will inform the conduct of a proposed longitudinal study, projected to be administered over a three year period.

PURPOSE The purpose of this study is to investigate student understanding of their own capacity to develop skills in thinking analytically and creatively in a second-year mechanical engineering design course.

APPROACH A two part instrument based on, but not replicating, Student Experience of Learning and Teaching (SELT) questionnaires has been administered to second-year undergraduates studying Design Practice in Mechanical Engineering. The questionnaires were designed to elicit information relating to student opinion, experience and self-assessment of their capacity for thinking creatively and analytically. The survey instrument is both quantitative and qualitative in nature and is prefaced by a small section for collection of demographic data. A mix of open-ended questions and likert-scale questions were included.

RESULTS A preliminary examination of the results of the two-part survey reveals an enormous depth of data indicating detailed self-assessment reflections from the participants. This paper focuses on the qualitative responses, using an open-coding method, commensurate with grounded theory, through which themes emerge from the data. Results of the open-coding indicate initial identification of their preferred approaches to problem investigation, as well as a recognition of their capacity to further develop critical and creative thinking. Preliminary analysis of quantitative data is also provided in this discussion.

CONCLUSIONS One hundred and twenty two students representing 54% of the class responded to the pre self-assessment survey and one hundred and four students (47% of the class) responded to the post self-assessment survey. The approximately 3,000 student responses, to the pre and post questionnaires, indicate the preparedness of students to engage in reflective practice related to their own learning. Whilst open coding of the responses provides some level of understanding of how students characterise this learning, the degree to which the learning has had a positive effect is yet to be examined in detail. However, it is evident that a significant number of students identify that their capacity for creativity and problem analysis increased over the semester long course.

KEYWORDS Critical and creative thinking, self-assessment, assessment for learning, and research as learning.

Introduction

Strong connections between creative thinking and problem solving in engineering have long been recognised. However, despite the emphasis placed on creativity as a ‘key capability that engineering students should master’ (Zhou, 2012), less is known about students perceptions on their own understanding and development of creative capacity in engineering.

According to Cropley and Cropley (2009) in engineering, the success of the Russian satellite ‘Sputnik I’, in 1957, was linked to ‘superior creativity’ of Russian engineers. Dickson (2001, cited in Cropley, 2016) identifies this event, characterised as ‘Sputnik Shock’, to be the catalyst for recognition and inclusion of creative approaches as an essential part of engineering problem solving. ‘Sputnik Shock’ was considered

> *‘…pivotal to the process of linking creativity (the generation of effective novelty), innovation (the exploitation of effective novelty) and engineering (the design and development of technological solutions to problems) in a systematic and scientific way.’*

This process has generated a growing body of knowledge around recurrent themes and connections between divergent thinking, innovation, creativity, problem solving and the engineering design process (see for example Dym and Little, 2004, Snider *et al.,* 2013, Howard *et. al.,* 2008). Additionally, the importance of creativity as a key capability of future engineers has been discussed by numerous bodies including the (US) National Academy of Engineering (2004), which names creativity as one of nine attributes essential to ‘The Engineer of 2020’ and by UNESCO in their 2010 report ‘Engineering: Issues, challenges and opportunities for development’.

The importance of creative and critical thinking in engineering problem solving is also acknowledged by Engineers Australia (2013), in the Stage 1 Competency Standard for Professional Engineers. Competency 3.3 ‘ Creative, innovative and pro-active demeanour’, encapsulates this in the expectations that engineers apply ‘creative approaches to identify and develop alternative concepts, solutions and procedures…’. However, the development of approaches to foster creativity amongst engineering students’ remains poorly understood (see for example Ballie, 2002, Cropley, 2016). Therefore, to inform learning and teaching practice in creative and critical thinking it is important to firstly gauge students own perceptions of their understanding, and of their own learning approaches.

As part of a larger study into the development of students' analytical and creative skills in the context of a second-year design course, this paper reports on a preliminary investigation into students' self-perceptions of their own learning in these areas. This study also serves as a pilot to a larger comparative study between Queens University, Canada and The University of Adelaide (UoA), Australia. Results of the pilot study will inform the conduct of a longitudinal study, projected to be administered over a three year period.

Methodology

The design of this research study is based on grounded theory and principally reflects a social constructivist approach (see for example Vygotsky, 1978, Wood *et al.,* 1976). Grounded theory has been chosen because of its use in understanding social phenomena. Using a grounded theory design was also decided upon because of the action based nature of the approach, and because this approach is reflective and co-participatory; involving both the respondents (students) and the researchers (educators) in the processes of learning. As students complete the surveys they are prompted, by the nature of the questions, to engage in higher order reflective practice, including evaluative and analytical reflection on their learning. In a similar manner to that of inquiry-based learning, the methods used in this research study are constructivist and presume a social context within which students’ perceptions of their learning and specific capacities in different areas are formed. For the purposes of this study, the social context is assumed to be the “classroom”.

Adapting some aspects of the of Queens University, Student Assessment of Teaching (USAT) questionnaire to the context of a second-year design course a two part questionnaire was administered to undergraduates studying Design Practice (Mech. Eng. 20) at The University of Adelaide. The questionnaires were devised to elicit information relating to student opinion, experience and self-assessment of their capacity for thinking creatively and analytically. Whilst the survey design is based on USAT, the form and intent of the design has a direct correlation to the Student Experience of Learning and Teaching questionnaire of The University of Adelaide (SELT), in that both surveys contain a mix of Likert scale measures and open-ended questions. The similarity of the questionnaire styles was intentionally chosen to provide a sense of familiarity and promote a more relaxed atmosphere for student respondents.

To ensure anonymity of the respondent’s names were removed from the submissions. A research assistant external to the course was engaged for this part of the process and for the open-coding.   Students from within the course have, subsequent to course completion, been involved in analysis and discussion of the data.

Questionnaires

For the current study, the first of the specifically designed questionnaires was administered to the target populations within the initial week of commencing the second year Design Practice (Mech. Eng. 2100) course. The second questionnaire was then administered at the end of the course and before examinations.

Self-Assessment Survey 1 (SAS1)

This survey instrument, consisting of 13 questions, was the first to be administered. The following four open-ended were designed to help students contextualise the nature of the survey.

1. *What capacities and abilities do you, personally, possess and which you consider contribute to you being an effective student engineer? Include reasons why you think each one contributes to your effectiveness.*
2. *How do you feel about having to study Design Practice as a core course?*
3. *What are your explicit goals for completing Design Practice?*
4. *How will you recognise if you have met your goals?*

The Likert scale statements were designed to provide students with a scale on which to quantitatively rate their own understanding of thinking critically and creatively in relation to problem solving upon entering the course, for example;

5. *I am easily able to devise alternative solutions to engineering problems.*
6. *I am easily able to apply the design method to solving engineering problems.*

8. *I can readily identify constraints and define specifications related to engineering problems.*

9. *I have high level skills in thinking analytically*

Four of the quantitative statements were followed by opportunities for the respondents to comment on reasons or examples to elucidate their answers.

10. *I am a highly creative thinker.*

Provide example(s) to illustrate your answer.

11. *I have high level skills in solving complex problems*

Provide example(s) to illustrate your answer.

12.Thinking creatively is a valuable skill for professional engineers.

What practices, processes and 'tools' do you employ to promote creative thinking in your own engineering studies?

13.Engineers use a broad number of processes and 'tools' to optimise their capacity to solve complex problems.

What practices, processes and 'tools' do you employ to promote your own capacity to solve problems?

Self-Assessment Survey 2 (SAS2)

This survey instrument, consisting of 16 questions, was administered as the end of the semester. The first four questions are deemed exit information, requiring the respondents to engage in higher order reflections by justifying their assessment.

1. Did your understanding of your own capacities and abilities, which you consider contribute to being an effective student engineer, change over the course of your studies in Design Practice?

In what ways?

2. Did your feelings about studying Design Practice change over the course of your studies?

Please explain why / how.

3. Did your explicit goals for completing Design Practice change over the course of your studies?

Please explain why / how.

4. In what ways have you now have met your goals?

The eleven subsequent questions refer directly to student's individual perceptions of their own learning and how it may have changed over the semester; in this case their perceptions are rated upon completion of the course. Four of these questions are quantitative with answers to be recorded on a seven-point Likert scale, designed to enable students to attach a measurement against their response.

7. My capacity to identify constraints and define specifications related to engineering problems has increased.

9. Over the course of Design Practice my ability to think about what I am doing and why, when solving engineering problems, increased.

10. As a result of Design Practice, I am confident that I can advance my own practice in solving engineering problems.

11. My capacity to draw conclusions from my experience, activities and outcomes, and extrapolate to other situations has increased as a result of studies in Design Practice.

Seven questions are designed to elicit a measure of agreement or disagreement to a statement (on a separate likert-scale) plus opportunity for qualitative comment, providing opportunity for the students to qualify their reasoning (on level of agreement/diagreement).

5. My capacity to devise alternative solutions to engineering problems has increased.

In what ways?

6. My capacity to adapt the design method to non- engineering problems, in order to optimise potential solutions has increased.

Please provide examples.

8. Reflecting on your skills at the beginning of the course; how would you rate yourself at that time, "I can readily identify constraints and define specifications related to engineering problems."

Why do you think this has changed / not changed?

12. My capacity to think creatively and apply creative ideas to complex technical problems has increased as a result of my studies in Design Practice.

Provide example(s) to illustrate your answer.

13. I enjoy solving complex engineering problems

Provide reasons for your answer

14. My self- motivation to learn has increased over the course of Design Practice.

Provide evidence from your experience or activities to exemplify your answer

15. My desire to further develop skills in thinking creatively and problem solving has increased over the course of Design Practice.

How might you apply these skills to other areas of your studies or life?

The final question relates to recommendations of ideas for further fostering students' capacity to think creatively.

16. Please suggest ideas for how you think we could help students develop their capacity for creative thinking and complex problem analysis.

The nature of this question falls within the highest level of reflective practice; concluding reflection, 'a reflection that draws conclusions' from the students 'experience of the activity' (Dowling *et al.,* 2013, p.196).

Method of Analysis

Over 3,000 responses, from students' to the pre and post course self-assessment questions, were recorded. This paper focuses on the qualitative responses, using an open-coding method, commensurate with grounded theory, through which themes emerge from the data. The nature of grounded theory dictates that the method of analysis of the data is interpretive. To assist in the analysis, the researchers need to be engaged in a continuous process of reading, reflecting and reviewing in order to confidently identify, record and propose relationships between themes, concepts and categories emergent from the data.

As SAS1 contained demographic data, it introduced a risk of researcher bias in the grouping of long answers. Therefore, for the data analysis, the demographic information from SAS1 was removed to prevent bias from influencing the coding.

Beginning with the first question, the data were then grouped in the following fashion.

1. After reading through the data several times and making notes on the properties of tentative groupings, the first 40 respondent answers were re-read as a sample and a series of 2-4 discrete themes were identified. Note that NA (Not applicable) is not a theme, but is considered a valid response.
2. The data, related to each question was then classified according to the appropriate theme.

This process was repeated in a similar manner for the SAS2 dataset, with the exception of demographic data, which was not part of the SAS2 dataset. In this case a series of 2-5 discrete themes were identified.

Results and Conclusion

Results of the open coding indicate initial identification of students' preferred approaches to creativity and problem investigation, as well as a recognition of their capacity to further develop critical and creative thinking. For each question between two and five themes emerged. Across the responses in SAS1 29 separate themes have been identified through the initial open coding, and an additional 40 themes have emerged from the responses in Survey 2. Whilst a more detailed level of coding is yet to be undertaken, some preliminary analysis has been attempted with qualitative, open-ended questions, selected to allow the direct comparison between Survey 1 and Survey 2, listed in Table 1. The themes listed are ranked and the number of responses are indicated in brackets.

Table 1. Evolvement of themes between Survey 1 and 2.

	1. Capacities and abilities, which you consider contribute to being an effective student engineer			
S-1	1. Developmental (42)	2. Analytical (38)	3.Team (11)	
S-2	1. Understanding (48)	2. Skills (27)	3. Teamwork (15)	4. Communication (3)
	2. Feelings about having to study Design Practice as a core course			
S-1	1. Practical (41)	2. Intellectual (40)		
S-2	1. Understanding (44)	2. Interest (19)	3. Workload (11)	4. Team (9)
	3. Goals for completing Design Practice			
S-1	1. Developmental (57)	2. Academic (25)	3. Competitive (9)	
S-2	1. Developmental (46)	2. Academic (25)	3. Competitive (6)	
	4. How will you meet / have you met your goals?			
S-1	1. Academic (41)	2. Developmental (37)	3. Competitive (7)	
S-2	1. Developmental (60)	2. Academic (29)	3. Competitive (7)	

Themes for both Q1 (*Capacities and abilities, which you consider contribute to being an effective student engineer*) and Q2 (*Feelings about having to study Design Practice as a core course*) significantly evolved between Survey 1 and Survey 2. Themes changed and their number increased from 3 to 4 for Q1 and from 2 to 4 for Q2 suggesting change in students' perception of the course and its requirements associated perhaps with increased level of understanding allowing more detailed assessment. In Q1 in Survey 1 majority of students listed developmental abilities (e.g. logical thinning, self-discipline) and analytical abilities (maths, physics) as most important with some students also emphasizing the importance of working in a team. In Q2 in Survey 1 students anticipated the course to expose them to both practical (e.g. application of theory to practical problems) and intellectual (e.g. learning specific design skills) development. In Survey 2 answers to both Q1 and Q2 shifted to more general understanding (understanding of Design Process with its many aspects and complexities including problem solving skills and creative thinking) making it by far the largest theme.

Themes for Q3 (*Goals for completing Design Practice*) did not change significantly with developmental theme by far largest followed by academic and competitive groupings.

Interestingly in Q4 *(How will you meet / have you met your goals?)* there was a big shift from academic to developmental theme between Survey 1 and 2 with students realizing that the main indicator of achieving their goals was their ability to learn how to tackle engineering problems rather than high marks. This realization was reflected in the Survey 2 quantitative questions (summarized in Table 2) and many comments.

Table 2. Survey 2 – Summary of Likert scale statements

Statement	Agree %	Neither %	Disagree %
5. My capacity to devise alternative solutions to engineering problems has increased.	84	15	1
6. My capacity to adapt the design method to non-engineering problems, in order to optimise potential solutions has increased.	62	36	2
7. My capacity to identify constraints and define specifications related to engineering problems has increased.	88	11	1
8. Reflecting on your skills at the beginning of the course; how would you rate yourself at that time, "I can readily identify constraints and define specifications related to engineering problems."	51	33	16
9. Over the course of Design Practice my ability to think about what I am doing and why, when solving engineering problems, increased.	83	16	1
10. As a result of Design Practice, I am confident that I can advance my own practice in solving engineering problems.	76	23	1
11. My capacity to draw conclusions from my experience, activities and outcomes, and extrapolate to other situations has increased as a result of studies in Design Practice.	75	23	2
12. My capacity to think creatively and apply creative ideas to complex technical problems has increased as a result of my studies in Design Practice.	70	27	3
13. I enjoy solving complex engineering problems.	78	21	1
14. My self- motivation to learn has increased over the course of Design Practice.	65	32	3
15. My desire to further develop skills in thinking creatively and problem solving has increased over the course of Design Practice.	77	19	4

The quantitative questions in Survey 2 indicate students' belief that their ability to solve engineering problems improved over the course of Design Practice. Q9 referring to overall ability to solve engineering problems received 83% broad agreement, this was supported by Q5 referring specifically to capacity of devising alternative solutions (84% broad agreement), and Q7 referring to capacity to identify design constraints and define specifications (84% broad agreement).

While asked if the course helped them to develop creative thinking in relation to technical problems the broad agreement was also high (70% for Q12) with related Q11 on ability to extrapolate their experiences with 75% broad agreement and Q10 (ability to advance practice in solving engineering problems) with 76% broad agreement. In Q6, which received a slightly lower but still high 62% broad agreement, students were asked if their ability can be extrapolated to more general non-engineering problem solving. Q8 asked to reflect on their ability to solve engineering problems at the beginning of the course and only 51% of students believed that they could readily identify relevant constraints and define specifications at that time with unusually high broad disagreement of 16%.

Questions 13, 14 and 15 aimed to gauge how students' general attitudes towards solving engineering problems and their willingness to further their skills changed over the course of Design Practice. In Q 14 most students believe that their self-motivation to learn increased (65% broad agreement) and in Q15 they claim that their desire to further develop skills in thinking creatively and problem solving has increased (high 77% broad agreement). According to Q13, 78% of students enjoy solving complex engineering problems.

A more detailed level of coding and analysis of the data is yet to be undertaken. However, initial coding has revealed diversity of emergent themes that reflect the depth and richness of student understanding related to each question, and to perceptions of their capacity for creative and critical thinking related to engineering problem solving. As stated by one student 'the creative side of my brain was activated and I can now visualise how gears, belt drives and bearings work and think of new and innovative ways to improve/change a design to suit a different application'.

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Prior Knowledge and Student Performance in Idea Generation

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SESSION S2: Educating the Edisons of the 21st Century

CONTEXT Engineering graduates are expected to possess sound skills in generating creative ideas to open-ended problems. Belski and Belski (2016) recently compared the performance of undergraduate engineering students from four countries using an identical idea generation experiment and established that students enrolled in engineering degrees from the Royal Melbourne Institute of Technology (RMIT) performed statistically significantly below their international counterparts. Belski and Belski (2016) associated the established lag in performance with lack of knowledge in science that is caused by weak entry prerequisites to enter the majority of engineering programs in Australia. They have also proposed to reconsider entry science requirements in order to ensure that students accepted to engineering degrees in Australia are better prepared for the engineering profession.

PURPOSE This paper presents the outcomes of the same idea generation experiment that this time was conducted at the University of Melbourne (UoM). It was anticipated that prior knowledge in science possessed by students accepted into undergraduate engineering systems degrees at the UoM exceeded that of their RMIT counterparts. If it were the case and the idea generation performance of the UoM students exceeded that of RMIT students, concerns raised by Belski and Belski (2016) would be validated and would require urgent attention by engineering educators.

APPROACH Ninety three students who have just enrolled in engineering systems degrees at the UoM were involved in an identical experiment to that conducted by Belski, Hourani, Valentine, & Belski (2014). Ideas generated by these students were assessed by two independent assessors that used the same evaluation criteria as the earlier study (Belski et al., 2014). In order to make a more accurate judgement of students' science knowledge they were also asked to identify their secondary school choices of the science subjects.

RESULTS The number of independent ideas and the breadth of these ideas generated by students from the University of Melbourne exceeded that generated by RMIT students. Students from the UoM Control group outperformed RMIT counterparts statistically significantly. Their performance was in line with the performance of students from Czech Republic and Russian Federation. Also, idea generation performance of students from the UoM Control group moderately and statistically significantly correlated with the number of science subjects they studied at secondary school. It was found that experimental treatment influenced idea generation more than prior science knowledge.

CONCLUSIONS The findings partly support the conclusion of Belski and Belski (2016). For the Control group students, who were not influenced experimentally, prior science knowledge did matter; thus, the concerns raised by Belski and Belski (2016) stand. As such, it seems wise for Australian engineering educators to reassess the need for more stringent entry science requirements for engineering degrees. Further research is required to establish the influence of science knowledge and experimental treatment on idea generation.

KEYWORDS Prior knowledge, science knowledge, creativity, idea generation, STEM education, engineering education.

Introduction

Engineering graduates are expected to possess sound skills in generating novel designs and innovative solutions to existing problems. It is therefore no surprise that Engineers Australia has identified creativity as one of the important skills for engineering graduates to possess in the 21st century (Engineers Australia, 2011); furthermore, the Department of Employment has included the skills "identify and solve problems" and "create and innovate" amongst 10 Core Skills for Work (Department of Employment, 2016). However, recent statistics on engineering vacancies in Australia, as well as on the numbers of Australian engineering graduates, indicate that many engineering graduates might be unable to get jobs with established companies and may need to think of launching their own businesses (Engineers Australia, 2017; Stewart, 2017). In light of this, a recent Deloitte report mentioned these particular skills as increasingly important for the success of Australian businesses by 2030 (Deloitte, 2017).

Belski and Belski (2016) suggested that Australian engineering graduates might be lagging their counterparts from other countries in their ability to generate novel ideas to open-ended problems. They compared the performance of undergraduate engineering students from four countries in the same idea generation experiment and established that students enrolled in engineering degrees at the Royal Melbourne Institute of Technology (RMIT) performed statistically significantly below their international counterparts in terms of both the number and breadth of ideas generated. Belski and Belski considered the following seven factors that could have contributed to the significantly lower performance of RMIT students: *"(a) differences in prior science knowledge of the student participants, (b) differences in their experiences, (c) dissimilarity in their creativity skills, (d) differences in student motivation during idea generation, (e) differences in experimental conditions, (f) cultural and language differences as well as (g) the influence in the treatment that the experimental groups were under"* (p.2).They concluded that the main reason for such poor performance of RMIT students was due to their insufficient knowledge of science.

In order to appraise the validity of Belski and Belski's conclusion on the critical influence of scientific knowledge on idea generation in engineering, the original idea generation experiment was repeated at the University of Melbourne (UoM). Although both universities had the same minimum requirements for VCE study scores in Mathematical Methods and English, the UoM also required a study score of at least 25 in one of Biology, Chemistry or Physics. Additionally, the Clearly-In ATAR for RMIT was 75, while for UoM it was 85 and so it was expected that students that enter science study at UoM with the intention to complete an "engineering systems" major have better science knowledge than those that enrol in an engineering degree at RMIT. This would then imply that the idea generation performance of students from UoM in the experiment should exceed that of RMIT students and be on the par with that of students from foreign countries (Belski & Belski, 2016). In essence, this study tried to establish whether the following three hypotheses are true:

1. Hypothesis 1: The Control group from UoM will statistically significantly outperform the Control group from RMIT.
2. Hypothesis 2: The MATCEMIB+ from UoM will statistically significantly outperform the MATCEMIB+ group from RMIT.
3. Hypothesis 3: Additional science knowledge helps students to generate more ideas and with greater breadth.

Methodology

Ninety-three students that have just enrolled in the Bachelor of Science degree at the University of Melbourne participated in this study, using the same idea generation experiment that was originally conducted by Belski et al. (Belski et al., 2014). Twenty two percent of the participants graduated from secondary school in Australia; 78% were international school graduates.

Students from four tutorial groups participated in the experiment. Groups were randomly assigned to four conditions: one control and three experimental. All participants were given 16 minutes of tutorial time to individually generate as many ideas as possible for the same open-ended problem (to remove the lime build-up in water pipes). Prior to generating ideas, tutors presented students with the same PowerPoint slide for two minutes. This slide contained the problem statement and a photo of a cross-section of a pipe, half of which was covered with lime deposit. This slide is shown in Figure 1a. After a two-minute introduction to the problem that covered only the information presented in Figure 1a, all students were asked to work individually and to record as many ideas as possible to remove the lime build-up from the pipes. The form to record ideas was distributed to the students just before the problem was presented. The form was the same for the students of all four groups and was the same form that was used in the original experiment but with some extra fields for students to indicate whether they studied physics, chemistry, biology, mathematical methods and specialist mathematics at secondary school.

Students from the Control group were not influenced by any ideation methodology. After two minutes of problem introduction, they were allowed to think of solution ideas and to record them for 16 minutes. The slide shown in Figure 1a was presented to the students from the Control group for the whole duration of the idea generation session.

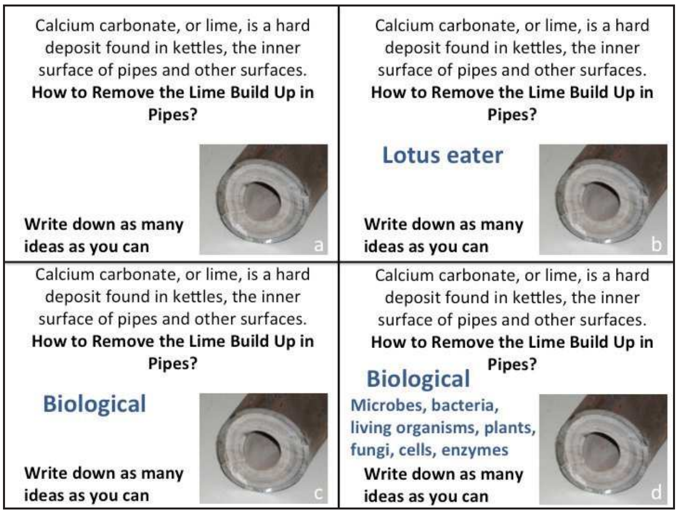

Figure 1: The Power Point slides presented to students: a) task introduction and Control group; b) Random Word group; c) MATCEMIB group; d) MATCEMIB+ group (Belski et al., 2015).

After two minutes of problem presentation, students from the three experimental groups were told that during their idea generation session some additional words will be shown on the PowerPoint slide. No explanation of what these words will be and what to do with them were given. Students from the Random Word groups were offered the eight random words that were used in the original experiment (i.e. Archaism, Right angle, Lotus eater, Emitter, Ozone, Blowhole, Ball-and-socket-joint and Hanky-panky). Students from the MATCEMIB group were shown the names of the eight fields of MATCEMIB (i.e. Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular and Biological). The MATCEMIB+ group students were presented with the names of the eight fields (in large font) as well as some words (in small font) that illustrated the interactions of the particular field (e.g. for the Mechanical field - friction, direct contact, collision, wind, etc.) The name of each field as well as each random word was shown to the students from the experimental groups for two minutes. Every two minutes a tutor changed the word on the screen and read the new word aloud. When a tutor of the MATCEMIB+ group changed slides every two minutes, they read aloud only the name of the field of MATCEMIB that was displayed in large font, but did not read the words that illustrated field interactions that were displayed in small font together with the field's name. Altogether the students from all groups were generating and recording ideas for 16 minutes. Figure 1 depicts one of the eight Power Point slides that were shown to students from different groups: Figure 1a – the Control group; Figure 1b – the Random Word group; Figure 1c – the MATCEMIB group; Figure 1d – the MATCEMIB+ group.

Results

General idea generation performance

Two independent assessors evaluated the student idea generation forms, using the same criteria as the assessors in the previous studies. These criteria were developed for the original study (Belski et al., 2014). Among other items, assessors counted the number of distinct (independent) ideas proposed by each student without necessarily assessing their practicality. In order to judge how broad these independent ideas were, each idea was assigned to a field of MATCEMIB that most closely matched the proposed principle of operation. The inter-rater reliability of assessment by the independent assessors was evaluated with SPSS by establishing the Cronbach's Alpha for the number of independent ideas proposed by each individual student. The Cronbach's Alpha exceeded 0.9, which suggested excellent internal consistency of assessment of the two assessors. Accordingly, the assessment of idea generation of students was evaluated as being very reliable. For further analysis, the number of independent ideas proposed by each individual student made by the assessors was averaged.

Table 1 presents the result for the average number of independent ideas proposed by the students in each group (Mean) and the breadth of these ideas (Breadth). It also contains information on the group sizes (N) and a percentage of local students in each group (*%Local*).

Table 1: Number (Mean) and the Breadth of distinct ideas generated by students from UoM

Group Information	UoM		
	N (*%Local*)	Mean	Breadth
Control	27 (*19*)	3.91	2.96
Random Word	25 (*24*)	3.30	2.48
MATCEMIB	18 (*17*)	4.17	3.61
MATCEMIB+	23 (*26*)	5.61	4.48

The breadth of ideas was calculated as a sum of eight terms, each equal to a fraction of students from each group that proposed distinct ideas that were assigned by the assessors to each individual field of MATCEMIB . For example, the following is the spread of the ideas for removing lime build-up proposed by the students from the Control group: 85% of students proposed Mechanical ideas; 7% - Acoustic; 74% - Thermal; 85% - Chemical; 19% - Electric; 7% - Magnetic; 11% - Intermolecular; 7% - Biological. Therefore, the breadth of ideas proposed by the Control group was equal to 2.96:

$$Breadth = 0.85 + 0.07 + 0.14 + 0.74 + 0.85 + 0.19 + 0.07 + 0.11 + 0.07 = 2.96 \quad (1)$$

The distributions of both the number and the breadth of ideas were not normal in some of the groups, therefore an independent samples Kruskal-Wallis test was conducted. It showed a statistically significant difference in both the number and the breadth of ideas between the groups ($p<0.001$). Pairwise comparisons (Dunn-Bonferroni) showed statistically significant difference in breadth ($Z=-3.656$, $p<0.005$) and the number ($Z=-2.708$, $p<0.05$) of ideas between the Control group and the MATCEMIB+ group. Similarly, the students from the MATCEMIB and MATCEMIB+ groups outperformed the peers from the Random Word group (MATCEMIB: breadth: $Z=-2.771$, $p<0.05$; MATCEMIB+: breadth: $Z=-4.814$, $p<0.001$; number:

Z=-4.261, p<0.001). Differences in performance between all other groups were not statistically significant.

Influence of scientific and mathematical knowledge on idea generation

Table 2 shows the percentages of students from the four groups that have studied physics, chemistry, biology, mathematical methods and specialist mathematics at secondary school.

Table 2: Percentages of students that studied science and mathematics at high school

Group	Physics	Chemistry	Biology	Math Meth	Spec Math
Control	100%	67%	41%	81%	70%
Random Word	80%	88%	40%	100%	48%
MATCEMIB	100%	78%	17%	83%	50%
MATCEMIB+	85%	95%	55%	91%	59%

The data presented in Table 2 suggest that science and mathematics knowledge of students from the four groups was likely to be similar and that the majority of participants were reasonably knowledgeable in physics and chemistry.

In order to assess the influence of knowledge of science and mathematics on the outcomes of idea generation, the individual score of science knowledge (SK) and the score of mathematics knowledge (MK) were introduced. Each study area was given a score of one and these scores were summed separately for science and mathematics for each participant. If, for example, a student stated that they studied physics, chemistry and mathematical methods, the science knowledge score was SK=2 and the score of mathematics knowledge MK=1. In the case when a student studied all five subjects at high school, both scores were the highest: SK=3 and MK=2.

Analysis of correlations (Pearson) of the breadth and the number of the ideas proposed by individual students from different groups and their individual knowledge scores in science and mathematics identified that statistically significant correlations (2-tailed, p<0.05) existed only for the students from the Control group and only with their science knowledge score (SK) (breadth: r=0.411; number: r=0.421). Neither the number, nor the breadth of ideas correlated with the score of mathematics knowledge (MK) in any group. The science knowledge score (SK) did not correlate with the breadth and the number of ideas for the students from the experimental groups.

Control and MATCEMIB+ groups: University of Melbourne versus others

Table 3 presents the result for the average number and the breadth of independent ideas proposed by the students from the Control and the MATCEMIB+ groups from RMIT (Australia), BUT (Czech Republic), KNASTU (Russian Federation) that were discussed by Belski and Belski (2016) and by the students from UoM (Australia) that participated in this study. Table 3 retains the original notations of Belski and Belski (2016) that identified statistically significant difference of the number and breadth of ideas generated by students from BUT and KNASTU with the corresponding values of the groups from RMIT. The **normal bold** font identifies statistical significance of p<0.001; the ***italicised bolded*** font a p<0.05. It is important to note that differences in performance between the same groups (Control or MATCEMIB+) from BUT and KNASTU were not statistically significant.

Table 3: Idea generation results of students from UoM compared with students from other universities (Belski & Belski, 2016).

Group Information	RMIT (2014)			BUT (2015)			KNASTU (2015)			UoM (2016)		
	N	Mean	Breadth	N	Mean	Breadth	N	Mean	Breadth	N	Mean	Breadth
Control	21	2.02	2.05	18	**3.56**	***2.53***	21	**4.32**	***2.57***	27	**3.91**	***2.96***
MATCEMIB+	18	5.13	4.44	18	***6.92***	4.56	23	***6.62***	***5.59***	23	5.61	4.48

The Mann-Whitney U tests showed that the Control group from UoM outperformed that of RMIT statistically significantly both in the number (Z=-3.740, p<0.001) and the breadth (Z=-3.003, p<0.005) of ideas. The difference in performance between the MATCEMIB+ groups of RMIT and UoM was not statistically significant. No statistical significance was discovered between the corresponding groups from BUT, KNASTU and UoM.

Figure 2 offers a graphical interpretation of the breadths of ideas proposed by students of the Control groups from RMIT and UoM that are presented in Table 3.

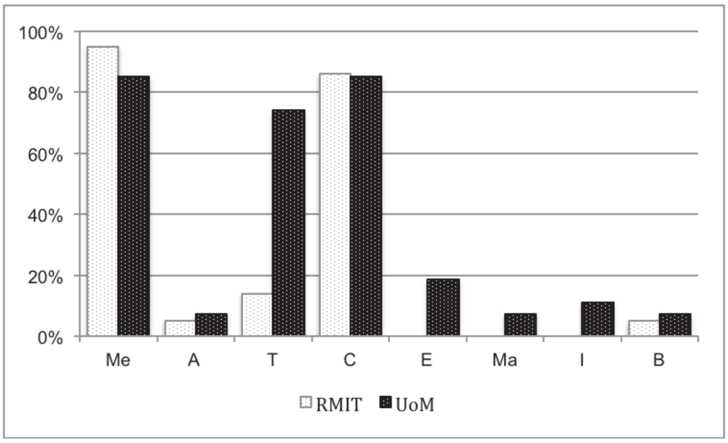

Figure 2: Percentage of students from Control groups of RMIT (light) and UoM (dark) that proposed ideas that belong to each field of MATCEMIB.

It can be noticed that the majority of students from RMIT suggested only solutions that belong to Mechanical and Chemical principles of operation (Breadth=2.05). At the same time, on top of the Mechanical and Chemical solutions, three quarters of the UoM students thought of solutions based on the Thermal principles of operation; nearly 20% also suggested ideas to remove lime build-up Electrically (Breadth=2.96).

Discussion

The overall results of the idea generation experiment at UoM, shown in Table 1, followed the pattern identified in previous experiments with students from Australia, Czech Republic, Germany, Finland, Italy and Russian Federation (Belski et al., 2015; Belski et al., 2014; Belski, Livotov, & Mayer, 2016). In particular, students from the MATCEMIB and the MATCEMIB+ groups outperformed their counterparts from the Control groups in both the number and the breadth of generated ideas. At the same time, students from the Random Word groups demonstrated mixed success; on some occasions, they did better than their counterparts from the Control group and on other occasions (as at the UoM) they did worse than their colleagues from the Control group. It remains to be seen why this is the case, however one possibility is that the random words may act as a distraction to some students that negatively affects their ability to generate ideas.

Only two out of three hypotheses of this study have been supported by the outcomes of the experiment.

The first hypothesis has been fully supported. The Control group from UoM statistically significantly outperformed the Control group from RMIT. Although this result supports the conclusion of Belski and Belski (2016) on the positive influence of science knowledge on the outcomes of idea generation, in this study the difference in performance between students from the UoM and RMIT could be explained by differences in many factors. The majority of the UoM students were from international (predominantly Chinese) background. They grew up under different cultural and language conditions and, most likely, had life experiences dissimilar to that of Australian students. These factors could have both boosted and inhibited student idea generation performance. Language differences, for instance, could have hampered the performance of the UoM students from an international background. The UoM students could have also had better creativity skills. The outcomes of the 2012 PISA assessment of creative problem solving positioned the 15-year-olds from four provinces of China that participated in the 2012 evaluation statistically significantly above their Australian counterparts (OECD, 2014). Students from Macao, Hong Kong, Shanghai and Chinese Taipei scored from 534 to 540 in the test. Australian students were on 523. Evidently, the results of the students from the four most economically advanced Chinese provinces cannot be generalised as performance of all students from China. However, it is possible that the creativity skills of international students from the UoM were above that of RMIT students.

The fact that the breadth and the number of the ideas proposed by students from the UoM Control group moderately and statistically significantly correlated with the science knowledge score (SK) favours the conclusion on the positive influence of science knowledge on the breadth and the number of distinct ideas made by Belski and Belski (2016). Clearly, the science knowledge score (SK) does not fully represent a student's knowledge in science. It does, though, offer adequate indication on the science knowledge that a student was exposed to. A person that studies physics is likely to be aware of more physical effects than a person who did not study physics. How would you, for example, propose to utilise electrolysis or cavitation if you have never heard of them? The absence of correlation between the knowledge score in mathematics (MK) and the outcomes of idea generation further supports the conclusion on the positive influence of science knowledge on idea generation.

It needs to be noted that the importance of general knowledge on creative performance has been advocated by Belski, Adunka and Mayer (2016). They surveyed engineering experts from some of the most innovative international companies and discovered that these experts value general knowledge (8.41/10) as much more important (statistically significantly) for creative performance then the discipline knowledge (7.00/10) and practical experience (7.21/10). General knowledge in terms of this experiment is represented by the science knowledge possessed by an individual student.

The second hypothesis has not been supported. The MATCEMIB+ group from the UoM was only slightly ahead of their RMIT counterparts on the count of independent ideas and their breadth but did not outperform them with statistical significance. The absence of statistical significance could be attributed to the significant representation of international students in the UoM MATCEMIB+ group; specifically, some international students might have had difficulties with English language. It is also possible that some international students, who came from different cultures, reacted to the MATCEMIB prompts differently to students from Australia and European countries. Overall though, the prompts appeared to work in improving idea generation – students from the MATCEMIB+ group outperformed their peers from the Control group in both the number and the breadth of ideas. At the same time, the eight words of MATCEMIB might have also confused some international students and inhibited the effect of the prompts. The latter explanation is supported by much lower performance of the students from the Random Word group compared to that of their Control group counterparts shown in Table 1. Such poor performance of the students from the Random Word group could likely be explained by the confusion created by the eight random words that were shown to them. Repeating the experiment at the UoM, in a semester when the enrolment ratio of local to international students is more in line with that from RMIT, may shed some light on the causes of the absence of a statistical significance between the MATCEMIB+ groups across institutions.

The third hypothesis has been partly supported. A moderate and statistically significant correlation was discovered between the number and the breadth of ideas generated and the science knowledge score (SK), but only for the Control group. None of the three experimental groups exhibited this correlation. This result implies that the experimental treatment (the words that were shown to students every two minutes) influenced the outcomes of their idea generation more than their prior knowledge in science, however this influence needs further investigation. Exploration of the level of school academic performance, as measured by ATAR score, and idea generation performance can further clarify the understanding of which factors influence the generation of ideas.

Conclusion

The findings of the study partly support the conclusion of Belski and Belski (2016). For the Control group students, who were not influenced experimentally, prior knowledge in science did matter when it came to generating ideas. Some students from the MATCEMIB+ group were likely to be influenced by the experimental treatment in a dual way. On one hand, it hinted to them the knowledge areas that held ideas on removing the lime deposit. On the other hand, the words shown to students without explanation could have puzzled some of them, particularly students from an international background. Consequently, further research is required to further clarify the influence of the experimental treatment on idea generation.

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Developing students' employability in work placements

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Abstract

SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Employer feedback consistently reports gaps in graduate professional capabilities. Developing graduates' work readiness is a goal of growing importance in the tertiary sector. Institutions are embedding curriculum and co- and extra-curricular activities to better develop student employability capabilities. While work placements are widely viewed as the best way to develop employability, employability learning activities in the curriculum can augment experiential learning.

PURPOSE The aim of this study was to explore the question

> *What preparation can develop student communication, networking and reflection skills before undertaking an engineering work placement?*

APPROACH A number of frameworks were used to guide development of new curriculum for employability. Eyler's reflective practice framework was used to enhance learning from experience, and an affordance model framework was used to scaffold learning, to prioritize learning during workshops to higher order skill development. A cultural values framework was used to guide learning about workplace culture.

RESULTS A workshop was developed for students looking for a placement that focuses on the application, networking and interviewing. A second workshop was developed for students who had already sourced a placement that focuses on key workplace learning opportunities: meetings, networking and reflection on experience.

CONCLUSIONS Well designed workshops can be an effective way to enhance student learning. Evaluation of outcomes and impact of the teaching innovation in employability lag interventions by several years, so longitudinal studies need to be carried out for a full evaluation.

KEYWORDS Work readiness, work placement, reflective practice.

Introduction

Many higher education institutions nationally and internationally have a strong focus on developing graduates' work readiness. The UK tertiary sector has made employability a key priority for the decade: "Embedding employability into the core of higher education will continue to be a key priority of Government, universities and colleges, and employers" (HEFCE, 2011, p5). The UK's Higher Education Academy (HEA) has responded by developing a framework to assist institutions develop employability in their graduates, through a process of building local ownership and implementing local solutions (Tibby and Cole, 2014), which has been used in 37 UK HE institutions to date. A key stage of the framework is to identify the right balance of curriculum, co-curricular activity, or extra-curricular activities for the institution. RMIT University's strategic plans focus on developing employability capabilities in all students prior to graduation through curriculum and co-curricular activities.

There is broad consensus that the extra-curricular activity work experience in the discipline field is the best way to develop graduates' employability (Orrell, 2011), although outcomes from work placements can be highly variable (Smith, Ferns, Russell and Cretchley, 2014) and demand exceeds supply (AWPA, 2013). A twelve-week engineering work placement is recommended by Engineers Australia (EA) as the gold standard for development of work ready capabilities, but EA now emphasize that it is not compulsory. They recognize that there are insufficient placements, as well as a variety of effective pathways to developing engineering competencies (I.Wood 2017, pers.comm., 20 Sept 2017). This supports the current HE focus on curricular and co-curricular activities to complement or substitute extra-curricular work experience.

The RMIT School of Engineering was formed from three former discipline engineering schools in 2016. In each former school development of students' employability skills relied heavily on a twelve-week engineering work placement. A new School wide elective course was designed in 2017 to replace each former schools' core work placement courses. The opportunity was taken to introduce scaffolding and capability development into the new elective course, to enhance student learning while on placement.

Eyler's reflection map framework was used to design the experiential learning WIL module. Eyler's framework systematically fosters individual reflection before, during and after a work placement. Self reflection is moderated through the lens of peer and supervisor interactions (Eyler, 2001). Pre- and post-placement workshops are run and during the placement students reflect, network with their peers, and correspond regularly with a university supervisor.

The concept of learning affordances was used to extend Eyler's framework to scaffold learning for employability. Affordance theory emphasizes the relational nature of use of materials, tools and technology in instructional design (Gibson, 1979; Evans et al., 2017). It focuses attention on increasing sophistication of capability level, from functional through perceived to contextual (Best, 2009). An affordances framework can be used to devise scaffolded learning activities to challenge perceptions of students and contrast contextual nuances (Fray, Pond and Peterson, 2017). Best's study of digital technology users defined three levels of affordance that are used in this study – functional, perceived and contextual (Best, 2009). Best also defined a maintenance affordance. However, significant advances of reliability in digital devices makes this much less of an everyday issue, hence this category may now be considered obsolete.

Hofstede's cultural values framework was used to incorporate socio-cultural learning for employability. The framework situates cross-cultural communication in terms of dimensions of individualism-collectivism, power-distance, uncertainty avoidance, masculinity-femininity, and long- versus short-term orientation (Hofstede, 1986). Organizational culture is seen through the lens of organizational practices distinguished by focus on process vs results; people vs. task; parochial vs. professional; open vs closed system; loose vs. tight control; procedures vs. market-driven (Hofstede, 1998). A deeper understanding of influence of societal culture as well as company culture on organizational practices will enhance graduate success in the workplace in an increasingly globalized economy. A practical application of Hofstede's framework is for students to undertake an ethnography of communication in situated learning. While participating in a company meeting, the student observes the behaviour of members of the company, to become "acquainted with the tasks, vocabulary, and organizing principles of the community", enabling their more rapid enculturation (Zhu and Bargiela-Chiappini, 2013, p.384). The observation task also contrasts their expert knowledge of their own culture (emic) with their novice knowledge of the company's culture (etic), facilitating their awareness of the need to adjust their own behaviour (Zhu and Bargiela-Chiappini, 2013).

This paper reports on design of WIL module workshops. The student's learning outcomes on placement are dependent on many aspects, such as project design and supervision quality as well as their personal knowledge, skills and attributes. While each student has his or her individual strengths and weaknesses, employer feedback continues to indicate gaps in graduate professional skills and emotional intelligence (Jollands, Clarke, Grando et al., 2015). The capabilities foci of training for students looking for work, or about to go on placement, are communication, networking, and interview and reflection capabilities. This paper outlines the theoretical basis for the curriculum design and identifies the evaluation approach that will be reported in future publications.

Curriculum Design

The WIL module workshop described in this paper was designed using a reflection map framework (Eyler, 2001) and learning was scaffolded using an affordance model (Best, 2009). Socio-cultural communication capabilities were developed using ethnographic observation using a cultural values framework (Zhu and Bargiela-Chiappini, 2013). The workshop aims to build students' knowledge, understanding, skills and confidence in communication, networking and reflective practice.

Eyler (2002 p.517) described the link between learning and community placements as

> *programs which thoroughly integrate service and academic learning through continuous reflection promote development of the knowledge, skills, and cognitive capacities necessary for students to deal effectively with the complex social issues that challenge citizens.*

Students undertaking work placements learn more from their placements if they reflect on their experience during their placement. Reflective practice is noted as a key capability in many professions. In engineering, many studies have reported on the benefits of reflective practice in design (Buccarelli, 1984; Blockley, 1999). In the health sector its contribution is described as "to learn effectively from one's experience is critical in developing and maintaining competence across a practice lifetime" (Mann, Gordon and McLeod, 2009, p.596). In teacher training, reflective practice has long been recognised as beneficial for teachers' learning (Roberts, 2009). However, little has been written about reflective practice for STEM discipline placements. The authors posit reflective practice will also enhance engineering undergraduates' workplace learning, which in turn will enhance their employability.

The concept of learning affordances used to scaffold the employability curriculum was based on Best's framework where

- Functional affordance is the experience of being able to use materials, tools or technology to accomplish a task.
- Perceived affordance is the experience of being able to get materials, tools or technology to do what the student wants.
- Contextual affordance is the experience of being able to integrate materials, tools and technology comfortably and profitably within the student's life.

Hofstede's cultural values framework was used to develop learning activities around cross-cultural communication (Hofstede, 1986) and organizational culture (Hofstede, 1998). The framework was used to construct an analytical rubric for students to record observations of work place meetings. Corporate and industrial workplaces in the 21st century are increasingly described as 'global' (Mohanty and Dash, 2016). We argue that a deeper understanding of influence of societal culture as well as company culture on organizational practices will enhance graduate success in a more globalized workplace.

The design of assessments will foster development of both employability attitudes and skills. This will be achieved through reflection on behaviour, as attitudes cannot be directly measured. Although they influence behaviour, "attitudes cannot be directly observed; they must be inferred through a person's various actions or pronouncements" (Willits, Theodori and Luloff, 2016, p.128).

The WIL module evaluation framework and validity of study results will be described in a future publication.

WIL Module participants and workshop description

The three-hour Workshop 1 described in Table 1 is a core module for 3rd year students who have had no engineering work experience. It is scheduled in Week 7 of a 12-week semester. Its aim is to enhance the students' ability to find summer vacation engineering work. Its focus is on careers and job hunting skills. It uses the affordance model to scaffold capability development.

The functional affordance level (F) is supported by activities completed by the students before the workshop. Participants must undertake research prior to the workshop and bring with them a current job advertisement, a current cover letter and resume, a near-future networking event, and a set of interview questions.

The workshop focuses on the perceived (P) and contextual (C) affordance level for each capability. Small group discussion or work in pairs is used to draw on students' prior knowledge of the perceived affordance level, and short presentations cover the contextual affordance level.

Table 1: Workshop 1 Looking for a placement

Capability	Affordance scaffold for learning outcomes
Communication	F Write a generic cover letter and CV P Articulate strengths using STAR (for cover letter, CV) C Write a cover letter targeted at a specific company
Networking	F Identify networking opportunities, top 5 companies P Prepare to engage at networking event (career objective) C Target events where your top 5 companies are likely to attend
Interview	F Be able to answer a range of standard interview questions P Be confident to dress right, and answer a range of behavioural

	questions C Elaborate on strengths relevant to the role with a variety of STAR examples

Learning is integrated through self-reflection activities, when students draft elements of their career plan using a plan template. Reporting back to the whole group is used to share ideas from the self-reflection. Adults hone their reflective capabilities most effectively through collaboration and sharing with others (Gray, 2007; Helyer, 2015).

The four-hour Workshop 2 described in Table 2 is a core module for BEng students who have been successful in sourcing engineering work placements for the summer. The course learning outcomes map onto the Engineers Australia Stage 1 competencies (Engineers Australia, 2017). The students enrol in the 12 CP course then participate in the preparation workshop prior to starting their placement. Multiple offerings are scheduled to cater for the approximately 500 students who start their placements at different points over the summer. On-line interactive video materials are available for those who are unable to attend.

Table 2: Workshop 2 Preparation for a placement

Capability	Affordance scaffold for learning outcomes
Communication	F Communicate with appropriate language and tone and relevant contributions in workplace meetings P Perceive cultural differences in communication – such as international cultural dimensions and interorganisational cultural dimensions C Adapt your communication style to fit with organisational culture
Networking	F Identify valuable intra-organisational networking opportunities P Engage effectively with colleagues at networking event C Target key intra-organisational events, develop an engaging elevator pitch
Reflection	F Reflect on own behaviour in dealing with a workplace issue P Perceive processes, relationships, organizational structures, practices, and any larger social, political and ethical issues that contributed to the issue C. Identified feasible strategies for you to bring about a better outcome in this specific context

The same approach to workshop pre-work and activities is taken as for Workshop 1. Each student is required to bring the cover letter and resume that they used to gain their current position, a list of network opportunities they might attend during their placement, and a reflection on their own role in a group work issue.

The workshop then focuses on the perceived and contextual affordance level for each capability. Students work in pairs, drawing on their prior knowledge, to articulate the perceived affordance level of communication capabilities. Working in pairs may also reveal to the students the benefits of peer-to-peer mentoring. Short presentations cover the contextual affordance level. Learning outcomes are again integrated through self-reflection activities. Students start to prepare for the assessments they will complete during the placement using a workshop work book. Reporting back to the whole group is used to share ideas from the self-reflection.

Assessment during the placement will focus on communication, networking and reflection capabilities. For communication, each student will observe behaviour in a company meeting. They will reflect on their own values (emic), and contrast this with the company's culture (etic), facilitating their awareness of the need to adjust their own behaviour to fit in (Zhu and Bargiela-Chiappini, 2013). For networking, each student will attend a company or external networking event. They will research the event, plan an approach and reflect on the outcomes. For reflection, each student will describe a current issue, the contribution of co-workers and organisational structure to the issue, and identify strategies that might bring about a better outcome in future.

Further Work

The teaching innovation will be evaluated using a mixed methods approach after the first workshop sessions scheduled for November 2017.

Students' self-reported capability level will be measured pre- and post-workshop by survey. Their perceptions of their capability level will be explored through focus groups.

Quantitative data will also be collected. Data on how many students are successful finding a work placement will be collected in 2018 as well as data on employment outcomes for the same cohort in 2020. A positive trend in the employment rates for this cohort compared to national trends would suggest the workshops are beneficial. There are a number of confounding factors that will also need to be taken into account, such as, the change from compulsory to elective work experience.

A continuing issue for innovations in employability capability development is the very long lag in data availability: the current 3rd year cohort will graduate in 2018, and the Graduate Outcomes Survey employment outcome data will be available only in mid 2020. Alternative methods of collecting employment outcomes sooner may be utilized, such as interrogation of LinkedIn profiles of alumni. LinkedIn profiles are also a rich source of data, as in addition to employment status, the employment sector can be ascertained.

Conclusions

Employer feedback consistently reports gaps in graduate professional capabilities. Developing graduates' work readiness is a goal of growing importance in the tertiary sector. Institutions are embedding their own distinct blend of curriculum and co- and extracurricular activities. While work placements are widely viewed as the best way to develop employability, embedding employability teaching and learning in the curriculum can augment experiential learning. Various frameworks can be used to guide development of new curriculum for employability. Reflective practice is a key to enhanced learning from experience, while the affordance framework allows scaffolding of learning in a systematic way, so workshop time can be prioritized to higher order capability development. A cultural values framework is useful to guide learning about company culture and its impact on communication. Well designed workshops can be an effective way to enhance student learning. A workshop before students apply for work focuses on job seeking skills. A workshop before students start their placement focuses on key workplace learning opportunities: meetings, networking and reflection on experience. Evaluation of outcomes and impact of the teaching innovation will be carried out over the next three years and reported in future publications.

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Student Experiences of Threshold Capability Development in a Computational Fluid Dynamics Unit Delivered in Intensive Mode

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SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

This study focuses on the student experience of passing through critical transformational thresholds, in a Computational Fluid Dynamics (CFD) unit delivered via intensive mode teaching (IMT) at a research intensive university. We define IMT as facilitated learning activity or classes delivered over fewer days and for longer each day than is traditional for the discipline. IMT is becoming increasingly common across the university sector as more students balance study and work, technology enables more options to access learning outside class-time, and universities teach offshore. Despite this popularity, best practice IMT has not been well understood.

PURPOSE

We sought to explore how features of IMT influenced students' threshold capability development in a CFD unit, and to identify, apply, and evaluate good practices for the delivery of a CFD unit in this mode.

APPROACH

The study is framed by the theories of threshold concepts and capabilities. We followed an exploratory phase with students and teachers, with a student survey. Based on findings, the unit was modified a year later, and qualitative data collection repeated.

RESULTS

Students' responses revealed that their experiences of threshold capabilities were not always as intended by academics – in particular, students focussed on issues associated with learning the CFD software package, rather than focussing on learning and applying the underlying theory, models, initial conditions and boundary conditions to develop valid models. As a result, the unit was re-designed to include a CFD software "boot camp" and weekly CFD software exercises, and the data collected from students in the modified unit indicated that the students were focusing on the intended threshold learning.

CONCLUSIONS

We recommend that educators identify the thresholds they hope that students will experience and investigate the students' experiences of thresholds in their units. If these differ teachers may be able to support students to more quickly overcome trouble that is not intended to be central to the unit.

KEYWORDS

Computational Fluid Dynamics, Intensive Mode Teaching, Threshold Concepts, Threshold Capabilities.

Introduction

Intensive mode teaching (IMT), namely facilitated learning activity or classes delivered over fewer days and for longer each day than is traditional for the discipline, is commonly used in industry. It is becoming increasingly common across the university sector as more students balance study and work, technology enables increased options to access learning outside class-time, and universities teach offshore. Despite this popularity, best practice IMT is not well understood. Therefore it was important to investigate how the practice affects student learning.

This study focuses on the student experience of passing through critical transformational thresholds, in a Computational Fluid Dynamics (CFD) unit delivered via IMT at a research intensive university.

Context

The unit is “Transport Phenomena”, and is intended as an advanced unit following on from fundamental units dealing with the traditional “transport” processes of Fluid Mechanics, Heat Transfer and Mass Transfer. The unit focuses on numerical solution of the Transport Equations and multiphase flow, with learning elements evenly divided between the underlying fundamental theory, and practical approaches and tools. The unit is designed primarily as a core unit for Chemical Engineering students in the penultimate or final year of a professional engineering degree (the 4^{th} or 5^{th} years of a 3x2 BS/MPE degree plan). During the years reported on here, the unit was offered as an elective, and was taken by 11-15 students; it has subsequently become a core unit in the chemical engineering program. The unit was also offered to Mechanical Engineering students as an elective.

This study is part of a larger project in which multiple intensive and matched non-intensive units were studied (Male et al., 2016).

The IMT model used in the unit

The first author developed and taught the unit. During the period considered, the unit was delivered over 8 weeks, with one full day workshop each week. While attendance was not monitored, attendance over the full class time was essential. The workshop sessions were not recorded, and there were in class assessments each week. Preparatory reading was assigned each week. The weekly workshops were structured (flexibly) as follows:

- The workshop started with a written test on the preparatory reading (30 minutes)
- The instructor then delivered lecture material on the week’s topic (60 – 90 Minutes)
- Peer briefings would follow, in which individual students briefed small groups. The briefings are assessed via students responding to instructor questions orally and on whiteboards in front of the class group (45-60 minutes).
- Group exercises would follow, designed according to the material covered that week – this could include formulation and calculation of 1D finite volume solutions of the transport equations, research exercises to identify literature (usually relevant to pending assignments), or exercises in designing model domains and meshes (60 Minutes).
- Finally, time would be allocated to work with the CFD software package used for teaching in the unit (ANSYS/FLUENT). In 2015, these exercises were largely self-directed; In 2016, a week 1 Fluent “Boot Camp” was implemented, and the instructor led skill development exercises in subsequent weeks (2-3 hours).

In both years, the major assessment items included:

- An assignment in which students developed a MATLAB code to undertake a finite volume solution of a problem involving transport of a scalar solely by diffusion (heat conduction in both instances).
- A Computational Fluid Dynamics (CFD) assignment, in which students developed a model for a well established case, evaluating the boundary condition and turbulence closure models, and validating their work against the published literature.
- A written exam, focusing on the fundamental theory of the finite volume method and multiphase flow. The written exam was closed book.
- A practical exam, requiring students to individually formulate and execute a Fluent CFD model in a set time (5 hours). The practical exam was open book and open internet (with the exception that students could not communicate with other parties during the exam).

Previous recommendations for best practice IMT

There are few studies on IMT. However authors have commonly recommended: front-loading the program with difficult and important concepts, supporting active learning involving practice and feedback, and encouraging peer interaction (e.g., Kops, 2014; Lee & Horsfall, 2010; Scott, 2003).

Methodology

We describe here the theoretical framework and how this influenced the research design. This study was framed within the theory of threshold concepts (Meyer & Land, 2003) and threshold capabilities (Baillie, Bowden, & Meyer, 2013). Threshold concepts are critical to future learning and practice in the discipline. Understanding of a threshold concept is transformative - opening up new ways of thinking and understanding, and therefore almost always troublesome. Common troublesome features are identified by Perkins (2006) and include complexity, requiring foreign ways of thinking, being abstract, and using new language. Threshold capabilities are similarly critical to future progress, transformative, and often troublesome, and usually require understanding of one or more threshold concepts. We use the term ‘thresholds’ to refer to threshold concepts and threshold capabilities.

Threshold concept theory is considered valuable for refining cluttered curricula (Cousin, 2006). By identifying threshold concepts and threshold capabilities curriculum developers can focus class time and students’ attention on the concept that are most critical to learn and for which students are most likely to need support. Similarly, we investigated curriculum features that influenced students’ learning, by focusing participants on the learning they experienced as most critical and troublesome by focusing their responses on thresholds they had experienced.

Method

In 2015, the second author held an in-class workshop with students taking the intensive CFD unit on the final day of teaching in the unit. After an introduction to the theoretical framework, students completed written questionnaires in which they focused on a threshold that they had experienced in the unit, and identified how it was troublesome and how they overcame it. They then responded to questions about features of the unit and their personal characteristics that had hindered or supported them in overcoming their identified thresholds (Male et al., 2015).

The second author interviewed the first author to identify the intended thresholds in the unit and to understand features that the students had described.

In response to findings improvements were made to the unit in 2016, and the in-class workshop repeated in the final class. The qualitative findings are reported in this paper.

Participants

In 2015, 11 (73.3%) of 15 students in the class consented to participate in the study. Their ages ranged from 19 to 26 at their last birthday (*M* = 22.0, *SD* = 1.9). In addition to basic demographic data, we were interested in demands on students' time because we expected this to contribute to students' learning in intensive mode. All 11 students were studying at least three units concurrently with this unit and one student studied four units concurrently with this unit.

In 2016, 16 (94.1%) of 17 students consented to participate. Their ages ranged from 21 to 38 at their last birthday (*M* = 23.3, *SD* = 4.2). Thirteen students were studying three units concurrently with this unit. Two were studying only two additional units and one student was studying four additional units concurrently with this unit.

One student each year worked for more than 20 hours in an average teaching week. Other participant characteristics are presented in Table 1.

Table 1: Participant characteristics (N_{2015} = 11; N_{2016} = 16)

		2015		*2016*	
Demographic Characteristic	*Values*	*N*	*%*	*N*	*%*
Sex	Female	4	36.4	2	12.5
	Male	7	63.6	14	87.5
English as a second language	With English as a second language	2	18.2	5	31.2
	Not with English as a second language	9	81.8	11	68.8
Domestic or international enrolment	Domestic	8	72.7	13	81.2
	Exchange	1	0.1	0	0.0
	International	2	0.2	3	18.8

Analysis

Following each workshop, the second author identified themes in the students' responses by question. Codes were informed by known troublesome features of threshold concepts, such as complexity and new language. Themes were also identified directly from the data. Codes were shared with the first author and we reduced the themes.

Findings and Discussion

Table 2 presents the themes that were identified in the workshop responses from students in 2015. The 2015 workshops returned an important finding – namely, that the dominant threshold reported by students was learning how to use the CFD software package. This was not the intended outcome – the focus should be on the fundamental theory of the finite volume method and its use to solve transport equations. Understanding the theory is essential to making the correct choices (model configurations, turbulence models, boundary conditions) when using the software package. The students, however, reported being more focused on the "mechanics" of the software package (how to create geometry, how to define a mesh, which controls to use). Drawing an analogy to algebra – this is akin to students focusing more on learning how to use their calculator than on learning how to manipulate equations.

Table 2: Themes among student responses in 2015

Threshold Concept or Capability	*Sample Comments*	*Comments*
Using CFD software to build meshes or solve problems	*Successfully building model using the required software.*	10
	Solving problems using ANSYS Fluent.	
How to use CFD software	*Learning how to use the software*	7
Theory of meshing for CFD	*How to discretise a space into "finite volumes" and iteratively solve for each element, and choosing an appropriate approach to solve.*	4
	Thinking in iterative method/control volume sort of way.	
Troublesome Features of Threshold Capability	*Sample Comments*	*Comments*
Taking time to develop	*It is learnt by experience and that means time, which is very limited.*	4
	It was like learning a new language. Needed to put in a lot of time understanding and practising.	
Foreign	*I never worked with the software. It was like learning something new. Also it was required to integrate the software modelling with the theory learnt in the class.*	3
Complex	*If wrong inputs are used, results generated by the software can differ largely from the analytical solution or diverge from real-world results. Thorough understanding of the models and the variables was required to successfully solve the problem.*	2
Features of the Unit that Hindered Learning	*Sample Comments*	*Comments*
Insufficient time for the necessary learning	*It is too short on TIME. Learning software takes experience and with only three weeks effectively to learn Fluent it is not enough.*	5
	Intensive mode didn't give me much time to learn as much as I would have liked because there was too little time.	
Having to learn to use the software independently	*There was no set way to learn the software-it involved individual research and was largely self-taught.*	3
How Students Learned	*Sample Comments*	*Comments*
Learned from online resources	*Online tutorials*	9
Practice	*Practice with the software and keep a diary with notes, relating each option of the software with theoretical understanding*	4
Interacting with peers	*Discussions with classmates*	2

Students reported having to learn to use the software independently as hindering their learning. Independent learning should generally be encouraged. However, it was taking too much time. Students reported using online resources to learn to use the software, and not having enough time to learn in the unit.

Based on the findings of the 2015 workshop, for 2016 more emphasis was placed on developing skill in the use of the Fluent software package. This started with a week 1 “boot camp”, where students were led through an introductory tutorial exercise. A weekly in-class skill development exercise was also introduced – the instructor would lead the group through new skills each week, though as the semester progressed the extent of “leading” diminishing and students were more independent. Each of these exercises were assessed via the submission of a particular model result – the selection of the result submitted was also a way to introduce new skills (animation, analysis, etc).

The effect of this change was immediate – it is plain from the 2016 workshop findings that while the software package remains problematic for some students, it was no longer identified as one of the most dominant thresholds, and students were focusing more on the underlying theory, as intended in the original unit design. Improvement was also evident in student performance – in 2015 two students failed the unit by failing to both complete the CFD assignment, and failing to submit any results in the practical exam. In 2016 all students successfully completed the practical exam. The small sample size cautions against drawing absolute conclusions, and this apparent improvement will be monitored in subsequent years. Themes among responses collected from students in 2016 are reported in Table 3.

Table 3: Themes among student responses in 2016

Threshold Concept or Capability	*Sample Comments*	*Comments*
Finite volume method	*Discretisation of differential equations that can be used to numerically solve equations* *Finite volume method* *CFD modelling*	11
Understanding the mathematics underlying CFD	*Understanding the models behind the software with the theory*	5
Modelling CFD equations in the software package	*Taking a problem geometry/domain and creating a working CFD model (including meshing and setting up boundary conditions)*	4
Using the specific CFD software	Using the software package ANSYS Fluent.	4
Troublesome Features of Threshold Capability	*Sample Comments*	*Comments*
Complex	*It involves complex math and there are multiple models/variations to learn.* *Requires strong understanding of calculus*	5
Textbook	*Initially just from reading the text I had no idea what was going on.*	3
Foreign	*Unexperienced with the program*	2
Language	*Language could be a problem to understand, need more time to study and get the theory*	2

Features of the Unit that Hindered Learning	Sample Comments	Comments
Issues with computing	*The program ANSYS is very user unfriendly and temperamental. The program often didn't work and you would waste hours on it and get frustrated.*	4
	Delays with computers/network/storage issues were frustrating when they affected my grade	
Heavy workload	*Large work volume and with many complex topics makes it difficult to keep up or pick an appropriate scope of understanding*	3

How Students Learned	Sample Comments	Comments
Interacting with peers	*Afternoon tutorials gave time to talk to peers about the program and resolve any issues I had*	8
	Peer briefings	
Practice	*Start with simple geometry/problems, adding more complexity or relaxing assumptions*	8
	Doing weekly fluent exercises	
Reading	*Read recommended textbook/resources to refresh knowledge and recommended resources that can help develop the software skills needed*	3

In discussing the features that helped students overcome thresholds, in 2016 not one student mentioned the weekly written quizzes, but the peer briefings were mentioned by several students. This indicates that in the presence of the peer briefings, which carry the strong motivating factor of having to speak in front of the group, the weekly written quizzes have become superfluous. They have accordingly been eliminated from the unit for 2017. Peer interaction and practice have frequently been reported as used by students to support their learning in the intensive and other units studied in the overarching project (Crispin et al., 2016; Smith, Compston, Male, Baillie, & Turns, 2016) and recommendations for IMT (e.g., Lee & Horsfall, 2010; Scott, 2003). In transitioning to a conventional teaching mode in 2017 (due to an increase in class size to 70), a modified workshop structure has been retained to maximize peer interaction within the larger group.

Theoretical explanation

Within the framework of threshold concepts and threshold capabilities, students are understood to experience a liminal space when the student is struggling with the threshold concept or capability (Meyer, Land, & Davies, 2008). In 2015 students were not entering the liminal space for the intended thresholds involving finite volume analysis. Students were struggling with the software and this created a barrier to the intended threshold learning in the unit. The findings collected in 2016 are consistent with the software boot camp in 2016 having supported students to enter the liminal space for the intended thresholds.

New recommendations for IMT

Previous studies recommended teaching the most difficult concepts early when using IMT. We found that additionally it was necessary to support students over unintended barriers to entering the liminal space for the intended thresholds.

Limitations and recommendations for further research

A limitation in the study is the small sample sizes due to low student numbers in the units. A limitation in the action taken to improve the unit based on feedback is that no action was taken to reduce the number of students concurrently taking three traditional mode units. This could be addressed in future work.

The introduction of the software boot camp highlighted the range of student capabilities, which makes leading group software exercises challenging. Handling this is a challenge for further research.

Conclusion

We recommend that educators identify the thresholds they hope that students will experience and investigate the students' experiences of thresholds in their units. If these differ teachers may be able to support students to more quickly overcome trouble that is not intended to be central to the unit.

Teaching strategies to ensure that students experience the intended transformative learning are good practice in any mode. However best practice may be even more important in intensive than other modes, and indeed aspects of best practice teaching such as peer interaction are facilitated by the extended continuous class-time available in intensive mode.

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Towards integration of the Māori world view and engineering: A case study on student design projects for the Koukourārata community, Aotearoa/New Zealand

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CONTEXT Among desired graduate engineer attributes is comprehension of the role of engineering in society and the economic, social, cultural and environmental impacts of engineering activity. The University of Canterbury, Aotearoa/New Zealand, aims for its graduates to be globally aware, engaged with the community and biculturally competent and confident. Here we present a case study on explicitly addressing the development of these attributes in a final-year undergraduate course. The key focus is the small coastal community Koukourārata, in Canterbury, for which students conducted a design project focussing on relevant water, sanitation and landscape management issues, guided by the Māori world view.

PURPOSE We present a case study that describes an inaugural design project in collaboration with the Koukourārata community, to highlight opportunities for community engagement and meaningful societal impact through the learning process.

APPROACH In previous years course design projects have been desktop studies on aspects of water, sanitation and energy systems in Pacific Island communities. With the 2017 inaugural design project in collaboration with the Koukourārata community in Aotearoa/New Zealand, students have been able to visit the area in question and meet with the community, and receive feedback on their designs. This approach aspires to respectful co-creation of sustainable and culturally relevant engineering solutions.

RESULTS Student design projects addressed aspects of domestic and agricultural/horticultural water supply, flood and sedimentation mitigation, food production, with various degrees of holistic treatment of integrated water and energy systems. These designs incorporated aspects of the Māori world views and beliefs. Designs gifted to the community provided the Koukourārata community with a diverse set of ideas and plans with which to achieve their aspirations for future development, and future years will add to the design portfolio. The course has directly addressed desired graduate attributes pertinent to societal engagement and sustainability.

CONCLUSIONS The opportunity for young engineers to engage meaningfully with indigenous peoples as part of their undergraduate programme, and the requirement for them to incorporate indigenous beliefs and world view into engineering designs to address significant water, sanitation, energy and land use issues, significantly enhances their educational experience. This approach starts to fulfil the need for students to understand the role of engineering in wider society and in developing communities in particular, in order to address complex issues of economic, social, cultural and environmental sustainability.

KEYWORDS Indigenous communities; Māori; Graduate attributes; Place; Treaty of Waitangi; Biculturalism

Introduction

In a world of continuing and increasing demographic and environmental changes, our future engineers must be sensitive to the sustainability of engineered systems in urban and rural settings. Key to this is being able to provide designed solutions tailored to the cultural expectations, needs and aspirations of particular communities. In this paper we offer a sharing of practice that presents an example of collaborating with one of Aotearoa/New Zealand's indigenous Māori communities, in order to present students opportunities to develop key insights and skills, as well as providing the community information and inspiration to meet their own development goals.

The Washington Accord is a multi-lateral agreement between international organisations responsible for accreditation or recognitions of tertiary-level engineering qualifications, and activities of the Accord signatories are meant to assist the mutual recognition of engineering qualifications among countries and regions (International Engineering Alliance, 2014). A fundamental element of the Accord is the articulation of desired engineering graduate attributes, a knowledge profile, complex problem-solving skills and attributes of complex engineering activities. These attributes are meant to reflect the skills necessary for successful engineering practice in today's modern world of complex projects, globalised work forces and the need to address environmental and socio-cultural concerns.

In the context of this paper, significant Washington Accord attributes and skills of note are: designing solutions that meet specified needs for cultural, societal and environmental considerations; reasoning informed by contextual knowledge to assess societal and cultural issues and the consequent responsibilities relevant to engineering practice; understanding and evaluating the sustainability and impact of professional engineering work in societal and environmental contexts; applying ethical principles; and functioning effectively as individual engineers and as part of teams in multi-disciplinary settings; and effective communication with the engineering community and society at large.

In addition, the graduate knowledge profile includes the need to demonstrate understanding of the role of engineering in society including the impacts of engineering activity on economic, social, cultural and environmental sustainability. When addressing complex engineering problems graduates are required to identity the range of potential conflicting requirements, and to identify diverse stakeholder groups with potentially widely-varying needs. Lastly, a key aspect of understanding complex engineering activities is to appreciate potential consequences to society and the environment in a range of contexts where prediction and mitigation may be difficult. The above aspects of graduate attributes, knowledge, problem-solving and understanding of engineering activities are intended to address important contextual factors that professional engineers must appreciate to ensure the success of their projects and teams, meeting needs of clients and other stakeholders, and ensuring sustainability in a world of growing populations, increasing urbanisation and environmental (including climate) change.

The University of Canterbury in Aotearoa/New Zealand has committed to ensuring graduates gain expertise in a core discipline, as well as developing a number of personal attributes that happen to align with many Washington Accord engineering graduate attributes. The four pillars of the University of Canterbury graduate profile personal attributes are: Bicultural Competence and Confidence; Engaged with the Community; Employable, Innovative and Enterprising; and Globally Aware (University of Canterbury, 2017a; Table 1). Elements aligning with socio-cultural emphases of the Washington Accord include: working effectively and professionally with diverse communities; analytical, critical thinking in diverse contexts; the ability to engage critically and effectively in global and multicultural contexts; and undertaking engagements, reflection and application of understanding in interactions with communities. Bicultural Competence and Confidence is given particular emphasis as a consequence of the institution's overarching obligations, as a Crown entity, to breathe life into the partnership central to the 1840 Treaty of Waitangi (signed by Crown officials & Māori chieftains). At its heart, bicultural competence is based on understanding that Aotearoa/Zealand's bicultural society is comprised of: 1) Tangata Whenua, people of the land - Māori and; 2) Tangata Tiriti, people of the Treaty - Europeans, others and their descendants in Aotearoa/New Zealand by virtue of the Treaty of Waitangi. This framework is intended to produce graduates who are distinctive in the knowledge, skills and attributes which position them to respond in the one nation, two peoples (Indigenous and non-Indigenous), whilst still acknowledging the multicultural society that is contemporary Aotearoa/New Zealand. This Treaty relationship, or 'biculturalism', also provides distinctiveness in an international context. For students at the University of Canterbury a key learning outcome is to "be aware of and understand the relevance of biculturalism in Aotearoa/New Zealand to their area of study and/or their degree" (University of Canterbury, 2017b). Students are provided opportunities to deepen their understanding *te ao Māori* (the Māori world) through studying *te reo Māori* (Māori language), *tikanga* (customary practice) and *kawa* (protocols). The *kaupapa* (themes) contributing to Bicultural Competence and Confidence are outlined in Table 1.

Table 1: The University of Canterbury graduate profile

<table>
<tr><th colspan="2">Critically competent in a core academic discipline of their degree</th></tr>
<tr><td colspan="2">• The core business of any University. Graduates will know and can critically evaluate and, where applicable, apply this knowledge to topics/issues within their majoring subject.</td></tr>
<tr><th>Bicultural Competence and Confidence</th><th>Engaged with the Community</th></tr>
<tr><td>• A process of self-reflection on the nature of "knowledge" and "norms".
• The nature of contemporary Māori organisational structures e.g. rūnanga[1], hapū[2], iwi[3], iwi corporations.
• Traditional and contemporary realities of Māori society e.g. tikanga[4] and kawa[5], Te Reo Māori[6].
• The Treaty of Waitangi and Aotearoa New Zealand's bicultural history.
• The processes of colonisation and globalisation.
• Other indigenous models of development, knowledge and behaviours.
• Application of bicultural competence and confidence in a chosen discipline and career.</td><td>• Engagement: Gaining knowledge and understanding of a community by interacting with a community.
• Reflection: Gaining knowledge and understanding of a community through reflection on one's experiences with that community.
• Application: Understanding and articulating how the content and/or skills of the subject/programme enhances the community.</td></tr>
<tr><th>Employable, Innovative and Enterprising</th><th>Globally Aware</th></tr>
<tr><td>• Working effectively and professionally with diverse communities.
• Communication.
• Analytical, critical and problem solving in diverse contexts.
• Digital literacy.
• Innovation, enterprise and creativity.</td><td>• Self-reflection on the nature of one's culture, language, and beliefs on one's systems of knowledge.
• Understanding the global nature of one's discipline.
• The ability to engage critically and effectively in global and multicultural contexts.</td></tr>
</table>

[1] community/tribal council, [2] subtribe, [3] tribe, [4] customary practice, [5] protocol, [6] Māori language

In addition to the graduate attributes emphasised by the Washington Accord and the University of Canterbury graduate profile, professional engineering bodies in Aotearoa/New Zealand address socio-cultural and environmental issues. The latest Code of Ethical Conduct adopted by the Institute of Professional Engineers New Zealand and Chartered Professional Engineers of New Zealand, in addition to specifying obligations relating to personal conduct, also specify obligations in the public interest (IPENZ, 2016). These public interest obligations comprise taking reasonable steps to safeguard health and safety, reporting adverse consequences, and having regard to effects on the environment. The latter obligation states:

> *You must, in the course of your engineering activities, i. have regard to reasonably foreseeable effects on the environment from those activities; and ii. have regard to the need for sustainable management of the environment. In this rule, sustainable management means management that meets the needs of the present without compromising the ability of future generations (including at least the future generations within the anticipated lifetime of the end products and by-products of those activities) to meet their own reasonably foreseeable needs.*

Although no specific mention is made in the IPENZ (2016) Code of Ethical Conduct of Aotearoa/New Zealand's indigenous Māori populations, the elements of environment and sustainability mentioned above are of particular concern to these communities.

Engineering in Developing Communities Design Project 2017

Background

The course ENCN401 Engineering in Developing Communities, offered through the Department of Civil and Natural Resources Engineering at the University of Canterbury, is a final 4th-Year (3rd Professional Year) elective that was first delivered in 2009. The course provides students with a background in development engineering, with a focus on potable water and sanitation systems, hygiene and disease, and rural agricultural engineering including irrigation. Other topics address the roles of women and disadvantaged groups, and socio-cultural factors that influence understanding and uptake of engineering solutions and behavioural interventions. The course draws upon the personal and research experiences of the lecturers in countries and communities across the world, and the material is framed through global agencies and initiatives such as the United Nations Development Programme, the 2000-2015 Millennium Development Goals and the 2015-2030 Global Sustainability Goals. An important component of the course is a design project conducted by groups of students, with the occasional support of local student chapters of Engineers Without Borders.

In 2016 new course material was introduced that addressed the history of Aotearoa/New Zealand and the impacts of humans on the environment. Two guest lectures also presented material on issues around marae (courtyard where formal greetings and discussions take place, and associated building complex) infrastructure (Te Puni Kōkiri, 2012), Māori as client, and the statutory role that Te Waipounamu/South Island iwi (tribe) Ngāi Tahu play in the rebuild of Ōtautahi/Christchurch following the 2010-2011 Canterbury Earthquake Sequence. The 2016 design project was a desktop exercise in which groups developed water, sanitation and energy solutions for a high school in Tonga, with information provided by the student Engineers Without Borders chapter at the University of Canterbury. Soon after delivery of the guest lectures, featuring Māori content, discussions began on 'how' the 2017 design project could be based in the Canterbury region and work closely with a local Māori community, with a specific focus on marae issues. This would give meaningful effect to the principle of 'partnership' central to the Crown's (1989-) 'principles for action on the Treaty of Waitangi' (Hayward, 2009).

The coastal community of Koukourārata/Port Levy was identified and one of the authors, M. Cunningham, a member the community, was engaged to determine local interest and potential collaboration. The concept was embraced enthusiastically, as the objectives of the wider course and the design project aligned with community aspirations. As a result, the course was now underpinned by an Indigenous place-based pedagogical framework similar to the curriculum design, delivery, assessment and evaluation processes recommended by Manning (2011; 2016).

Preparatory Curriculum Material

Preparatory lecture sessions focussed on three areas: 1) elements of community engagement; 2) design thinking and empathy with stakeholders; and 3) an overview of Māori history and the importance of marae, and Māori as client.

Initial lectures and exercises focussed on engaging community stakeholders through interviewing, observing and participation, drawing upon international experiences in the African and South Asian continents. The importance of information gathering was emphasised through triangulation – obtaining information from more than one source in a community and doing comparative assessments. In anticipation of the upcoming Koukourārata community visit, a place-conscious structure was presented in which to define the nature of engagement in comparison to strict ethnographic study, and market research to inform product/system design processes (Table 2). Information was presented on effective and respectful information in communities, including; explaining the type of interaction sought; gaining permission for any recordings whether visual or audio; in interviews, starting with easy open questions to gain trust, and asking for specific details, examples and stories.

Table 2: Defining the nature of engagement with the Koukourārata community (ENCN401 visits) in comparison with ethnographic and market research approaches

	Ethnographic Study	*ENCN401 Visits*	Market Research
Focus	Observe and record	*Involve and innovate*	Define and quantify
Outcomes	Extensive description	*Empathy and inspiration; Ideas; Prototypes*	Quantitative information; Feasibility
Type of Interaction	Long; Unstructured; In-depth	*Short; Unstructured; In-depth*	Short; Structured; Broad
Community Involvement	Everyone	*Cross-section of community; Local innovators*	Targeted market segments

A second set of preparatory lectures and exercises focussed on the design process and empathy with stakeholders. Students were introduced to the Design Spiral concept to emphasise that the path to solutions is not simple and linear. This framework begins with Stage 1 – Information and Insight (Learn), followed by Stage 2 – Ideas and Approaches (Ideate) and then Stage 3 – Implementation and Validation (Experiment); the process then returns to Stage 1 for further research and refinement and continuation of the spiral. The steps in this process were linked explicitly with community engagement and design output milestones throughout the course. Other material presented to the class included: definitions of human-centred and user-centred design, co-creation, and user-created design; and users' motivations and needs as framed by Maslow's Hierarchy of Needs (Maslow, 1943). To further be able to distil information into a statement of user needs the concept of a PATH Statement (Problem, Approach, Target, Heart) was introduced, in which the problem is stated clearly with sufficient contextual detail to demonstrate its importance, the approach to problem framing is described, targets are defined (especially quantitative ones), and that the anticipated outcome shows heart, or is sensitive to communities' needs, wishes and aspirations. Different approaches were presented for framing problems. Subsequent to the initial community engagement (see next Section), further material and exercises focused on better stakeholder characterisation. This was explored through the development of "personas" – representations of individuals based on researcher/designer experience of the community, and created as tools for empathy. Personas included: descriptions of individuals' demographics and cultural and social environments; characterising their world through imagining their social, economic and infrastructure constraints; and imagining a day-in-the-life narrative. Final topics comprised different approaches to brainstorming design solutions including convergent and divergent processes in concept generation (Liu et al., 2003), and discussing the roles of team composition and attitudes in creative design generation (Toh and Miller, 2016a; 2016b). Concept selection methods including Pugh Charts and Quality Function Deployment/House of Quality assessments (Okudan and Tauhid, 2008) were addressed, as were design sustainability and life cycle assessments (Devanathan et al., 2010).

The final preparatory session, to raise students' cultural awareness and place-consciousness levels, was an overview of the history of Māori in Aotearoa/New Zealand, the 1840 Treaty of Waitangi and colonisation impacts, the importance of marae in the Māori world, and the roles of Māori as clients and environmental guardians. The importance of marae was emphasised as a community centre, the pū manawa (beating heart or pulse) of the people who live around it; because important discussion and decisions take place on the marae they are viewed as politically significant. Discussion centred on the fact that ⅓ of marae have inadequate and unfit-for-purpose infrastructure (Te Puni Kōkiri, 2012), due to lack of funding and investment, rural communities not prioritised by local and central government, and issues around communal land ownership. The state of marae presented clear opportunities for the students to envision potential contributions to potable water, waste water, and energy systems. The importance of marae in disaster contexts was also highlighted further demonstrating their essential roles in communities (e.g. Lambert, 2014). Also explored was that due to the demonstration of Māori autonomy and resourcefulness in developing support networks during the 2010-2011 Canterbury Earthquake Sequence, the Ngāi Tahu iwi (tribe) have for several years been a statutory partner with local and central government in the rebuild of Christchurch City. Accordingly there has been significant Māori input into architectural design of buildings and their surrounding open spaces that tell of the ancestral ties to landscape from before European colonisation and construction of Christchurch's built environment. Newly designed features echo locations and lifeways associated with seasonal movements, food sources, water bodies and significant events in Ngāi Tahu's history.

Another significant preparation for community engagement at Koukourārata was an overview of marae protocol during the traditional welcome ceremony (pōwhiri). Preparation involved presenting written material and verbal instructions about what to expect, and what was expected of them (e.g. to wear formal attire as they represented themselves, their families and their ancestors), the manner of entering the marae, speeches and singing. A well-known Māori folk song originating from the early 20th century called *Tū Tira Mai Ngā Iwi* (Line Up Together People; a song exhorting community solidarity) was first practiced in the course's introductory lecture and again in the lecture session immediately prior to the marae visit. It should be noted that the actual pōwhiri process during the community engagements was conducted in te reo Māori, but the ensuing discussions were in English. Students were presented English translations of the pōwhiri visitor response speech delivered by M.W. Hughes so they could understand what was being said.

The Koukourārata Design Project

Koukourārata (Port Levy in English), is a local Ngāi Tahu rūnanga (community) situated on Banks Peninsula, on the southern margins of Lyttelton Harbour on Banks Peninsula, Canterbury, Aotearoa/New Zealand. Koukourārata has a long history of Ngāi Tahu, Kāti Māmoe and Waitaha land use and occupancy and holds a significant place in tribal history and traditions. The settlement and marae are located on the ancient pā (fortified settlement) site Puari. Koukourārata was the largest Māori settlement in Canterbury in the mid-

1800s with a population of around 400 and a reputation for its abundance of kai (food) – both māra kai (cultivated food crops) and kaimoana (seafood). The focal point of the modern community is Tūtehuarewa Marae, whose whare tipuna (ancestral/meeting house) was built in 1923 and named Tūtehuarewa after an ancestor. In 2004 a whare kai (dining hall) was added to the marae buildings, and was named Te Pātaka o Huikai (the storehouse of Huikai) after the eponymous ancestor Huikai. See Mahaanui Kurataiao Ltd (2017) for more details. The community is developing a successful project in conjunction with Lincoln University, Canterbury, to establish organic horticulture in line with the four Koukourārata strategic pou (pillars): 1) matauranga (knowledge/wisdom), including education and research; 2) economic development; 3) employment opportunities; and 4) bringing whānau (family) home/papakainga (original home/communal Māori land). The Koukourārata Development Company was established to give effect to the 2025 vision for the community: to protect and restore the mauri (life spirit) of the land and its water, and to engage and reconnect whānau with Koukourārata through creating employment, education enterprise and other opportunities. See Hapai (2017) for more information.

ENCN401 was invited to Koukourārata to meet with the community, learn about their history and values and to start working with them to address issues around provision of water for domestic use, agriculture and ecological restoration. There was also opportunity to address concerns around sanitation and energy. An essential element of the project was to spend time with community representatives to understand their issues and world views, to better enable sustainable and resilient community-centric designs.

The learning objective was to apply knowledge and skills to the design of an engineering solution for a well-defined problem related to water, sanitation or energy needs at Koukourārata, with the problem definition done in consultation with members of the Koukourārata rūnanga. Another key objective was to raise students' awareness of the social, economic and environmental issues that engineers must account for while working with developing communities. The class (total 37 students) was comprised mostly of students studying Civil and Natural Resources Engineering, with some studying in Forestry and Mechanical Engineering. Most students were from Aotearoa/New Zealand, but several were from North America and Europe. The class formed groups of 3-4 tasked with designing a practical and sustainable technology-based solution to a water, sanitation and/or energy problem. Although the focus was primarily on engineering solutions, groups had to consider social, cultural and economic factors impacting on successful design implementation.

Based on the preparatory lecture material and exercises groups were to first analyse the context and situation of the Koukourārata rūnanga, then define a particular issue to be addressed. This was followed by generating a suite of potential solutions, then narrowing these through concept selection. The project was executed via a series of milestones and community engagements described in Table 3. A valuable experience was the presentation of draft design solutions during a second day-visit to Tūtehuarewa Marae, providing students with valuable feedback from the rūnanga, and providing confidence that their designs were incorporating elements that directly addressed the community's aspirations.

The titles of submitted final projects are presented in Table 4. Projects addressed aspects of domestic and agricultural/horticultural water supply, flood and sedimentation mitigation, food production, with various degrees of holistic treatment of integrated water and energy systems. The final project reports and project posters/maps have been compiled, bound and gifted to the Koukourārata rūnanga. The intention is to over time build a library/portfolio of ENCN401 student designs for the community's reference, which may inform later detailed scoping and implementation to support local development initiatives.

Table 3: Koukourārata Design project milestones (M) and community engagements (CE)

M, CE	Task/Activity
M1	Identify team members
CE1	Spend weekend at Koukourārata and stay the Saturday night at Tūtehuarewa Marae. On the Saturday arrive and be welcomed in traditional pōwhiri, followed by education and orientation sessions run by the rūnanga. Sunday explore the area and speak to locals about relevant issues.
M2	*Problem definition report* that: 1) Clearly expresses underpinning values and approaches of the rūnanga towards the environment, natural resource utilisation, water and waste, and future development; 2) Identifies a water, sanitation or energy issue that groups wish to address, and qualitatively describe the problem, identify any potential for an integrated water-sanitation-energy solution; 3) Outlines proposal to define quantitatively characteristics of the issue and proposed solutions, identify further types of information needed; 4) Identifies necessary resources and constraints for project based on the information gained from visit and other sources. Constraints may include: terrain and climate characteristics, available construction materials, local labour skills, financial aspects, and local legislation.
M3	*Progress report* describing in more detail issue(s) addressed and potential solutions evaluated. Rationale presented for selecting a solution the project team will further develop. In addition to technical issues, attention paid to non-technical aspects as mentioned before.
CE2/M4	Spend Saturday at Koukourārata and Tūtehuarewa Marae. Each group to present a "mature" design to the rūnanga. Opportunity to showcase ideas and receive feedback to be incorporated into final project submission.
M5	*Final report* with detailed description of engineering solution to identified problem, supported by diagrams and calculations as appropriate. Emphasise role of technical (physical/engineering and scientific) and non-technical (economic, social, cultural) issues with respect to their interaction and how they shape technological implementation. Analyse how the technology meets the goal of sustainability. In-depth analysis of the technology using principles discussed in class. Describe how community feedback at the second marae visit was incorporated into final design.
M6	Reflection of evidence of student effort to engage with project, reflecting participation in activity. Garnered from students via a system allowing assessment of each other's relative contribution.

Table 4: Submitted Koukourārata design projects

Group	Design Project Title
1	Proposed irrigation and domestic water supply for Koukourārata
2	Proposal of a suitable potable water supply for the Koukourārata community
3	Flood mitigation for the Koukourārata community
4	Koukourārata olive grove proposition
5	Domestic water supply for Koukourārata
6	Taewa (Māori Potato) production through a hydroponics alternative for Koukourārata Marae
7	Sedimentation solutions in Koukourārata
8	Developing Koukourārata into an eco-community
9	Silt retention and economic stimulus package
10	Koukourārata Water Supply - A sustainable approach to a holistic water system

The ENCN401 class was surveyed to elucidate their experiences of the design project and engagement with the Koukourārata rūnanga. The survey was not part of the formal University of Canterbury course and teaching assessments, and response rate was poor. However, some useful and insightful comments were received.

Below are selected responses to the question: *The first part of [ENCN401's] lectures focussed on design thinking and idea generation, to arrive at culturally appropriate design solutions. Was this useful for the Koukourārata design project? If so, how?*

> *I did find this incredibly helpful as it made us take a step back and think more about what they want and need as they need to take ownership. It would have been even better if we had even more interaction with more people in the community while we were there.*
>
> *Yes some of [it] was helpful – I think it could be better applied in a [harsher] environment where there are significant language, cultural, social barriers – with more limited resources. The people from Koukourārata being from [New Zealand] were very open to help us achieve our goals.*
>
> *This was very useful, in the way that [it taught] us how to approach the community, and to expect that is would not be as easy as one may think. The members of the community may have a clear opinion of what is culturally acceptable, and how things work in the community, but this may be difficult to explain to us [who] have no knowledge. We experienced this in practice when we had both the meeting with [M. Cunningham at the University of Canterbury] and after our presentation at the Marae, that what we had understood [was] not totally correct.*

Below are selected responses to the question: *Having completed the Koukourārata design project, do you feel your understanding of Māori history/culture/worldview has changed? If so, how?*

> *Yes I definitely think I gained a much greater appreciation for Māori culture and I also really felt I understood why cultural diversity is so important in the world. I always knew it was the case but I had never been so confronted with it I suppose.*
>
> *Yes, I have a more exact understanding of especially their views of water and waterways, and what is culturally accepted in different situations. After personally interacting with the community I also feel more home and want to help the people and the area.*
>
> *Yes I have a more well-rounded perspective of how the Māori were previously treated and also how those effects have flowed on to the present day.*

Below are selected responses to the question: *In future, how do you think you might apply your Koukourārata design project experience?*

> *I think I will make sure to emphasise the importance of making people feel valued (I feel our idea achieved this), whilst also really listening to the [root] of the problem and trying to avoid preconceived ideas. I hope to do some entrepreneurial work to solve global problems, and I think a lot of the skills from the design project will be able to be applied. I also hope to work in developing countries and so it will be particularly relevant.*
>
> *The process and [technical] approach [are] experiences I for sure can use if I am working on a project in a developing community, but also when working with all kinds of stakeholders in project design and building projects. The [technical approach] will always have to be adjusted to the situation.*
>
> *If I am required to work with a particular Māori group it will be very helpful as I already know quite a lot of their core values and how to treat their culture. It was also good practice for dealing with potential clients. I do understand how the Māori are a developing community but compared to those in developing countries I think there is quite a big difference – it was still a valuable experience.*

We acknowledge the low survey response rate means that these student comments are not generalisable to the wider class. In future years class-wide assessments will be undertaken, and analytical frameworks will be developed with which to interpret them, such as the bicultural competencies presented in Table 1.

Taking stock, and the journey ahead

The 2017 inaugural Design Project in collaboration with the Koukourārata rūnanga has proven to be an interesting challenge for the teaching team and students, and will become a keystone in the course ENCN401 in years ahead. Although the sharing of practice presented in this paper cannot address metrics of success in a rigorous manner, future years will afford opportunities to develop appropriate metrics of students' bicultural competence, and wider failings and limitations from student and community perspectives that will be used to improve the course. The course incorporates aspects of design thinking, concept generation and selection, collaborative work, sustainability, and engaging with Aotearoa/New Zealand's indigenous Māori communities in the spirit of respectful co-creation. This approach serves two important purposes. First, the collaboration is helping provide the Koukourārata rūnanga with a diverse set of ideas and plans with which to achieve their aspirations for future development, and may serve as inspiration for their own youth to engage in Science, Technology, Engineering and Mathematics subjects throughout their education. It is hoped that aspects of student projects developed over time may be deemed sufficiently applicable to be scoped professionally and implemented to support Koukourārata's infrastructure and development. Second, the course ENCN401 and its Design Project directly address desired graduate attributes articulated by the Washington Accord (International Engineering Alliance, 2014) and the University of Canterbury (University of Canterbury, 2017a; 2017b), as well as addressing obligations in the public interest under the Code of Ethical Conduct adopted by the Institute of Professional Engineers New Zealand and Chartered Professional Engineers of New Zealand (IPENZ, 2016).

Looking ahead to 2018, the following will be done:

- The overall approach and structure of ENCN401 and its Design Project will be retained, but with some modifications made at the suggestion of students and teaching staff. These will include including more opportunities for environmental sampling and monitoring.
- Discussion will be had with representatives of the Koukourārata rūnanga on whether next year's projects should address particular themes e.g. impacts of natural hazards, climate change, aquaculture/marine farming, and sustainable energy. There is ample opportunity for this because this project is the first of many years of collaboration.
- In the preparatory curriculum materials more lectures will be devoted to developing place-based approaches to teaching about Māori histories in Aotearoa/New Zealand and Māori worldviews pertaining to their relationships with a diverse range of landscapes, water and the wider environment. Material on the 1840 Treaty of Waitangi and its ramifications will be included, including what this means for Aotearoa/New Zealand's bicultural society and its peoples i.e. Tangata Whenua (people of the land, Māori) and Tangata Tiriti (people of the Treaty, Europeans, others and their descendants in Aotearoa/New Zealand by virtue of the Treaty of Waitangi).
- Assessments will be made of students' cultural competence. This will involve written self-reflection exercises prompted by specific questions at the beginning and end of the course.
- In the final 4th Year (3rd Professional Year) of the undergraduate programme in the College of Engineering at the University of Canterbury, students are required to undertake a research project equivalent to ¼ of their year's course load. In 2018 two of these research projects will be dedicated to Koukourārata in addition to the design projects of ENCN401.

Beyond 2018, the following is intended:

- Continue over time to build a library/portfolio of ENCN401 student designs for the community's reference and inspiration;
- Continue to dedicate final-year research projects to complement ENCN401.

- Broadening the assessments of students' bicultural competence. In collaborative co-creation with the rūnanga, approaches including qualitative observation will be explored, as will the potential to apply participant-observer ethnographic research.
- Within the wider College of Engineering and Department of Civil and Natural Resources Engineering at the University of Canterbury, introduce more Māori content earlier in the undergraduate programme. Over time this will allow courses such as ENCN401 to build on this introductory material, and begin to address more complex and subtle issues of policy and legislation that impact on design implementation and sustainability.
- Engaging other rūnanga in the Canterbury region to see if the approaches being developed here can also be applied to other marae.

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Using Narrative Research Findings as Student Voice for Providing Insights into Transition Experiences in Engineering Education

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SESSION
C3: Integration of teaching and research in the engineering training process

CONTEXT
This paper presents a study of students lived academic transition experiences of graduates from a Pathway program after they have transitioned into a Bachelor of Engineering (Honours) program. The importance of pathways for upskilling the workforce and bringing more people into Higher Education (HE) system that wouldn't normally have the opportunity from the traditional entry is essential to the continuous growth of the modern industrial economy. Narratives collected from the research to investigate students' academic transition experience provide an insight into this transition that cannot be captured by traditional quantitative or some qualitative approaches.

The narratives' findings are useful feedback information into academic transition programs and training. The outcomes of this study will be used to inform the education management and facilitate change in the provision of transition services to suit students transitioning from Pathway program into a Bachelor of Engineering (Honours).

PURPOSE
This paper presents narratives from the investigation of the students' academic transition in engineering education from Pathway program to Higher Education.

APPROACH
This paper describes participants' insights into their academic transition experience using the narratives collected from a Narrative analysis. Narratives describe the stories of the participants as a unique data source, and different to the traditional coding and categorising aspects typically used to produce a generalised or transferable description. In so doing, present the participant's account as unique and a whole story.

RESULTS
A total of twelve cases were investigated using in-depth narrative interviews from which four cases will be presented to demonstrate the insights into the academic transition experience during Pathway programs. These four narratives are used to contextualise the importance of using the participant's voice and stories as a useful source of feedback in engineering education research.

CONCLUSIONS
Narrative analysis offers a different way of collecting feedback and analysing the lived transition experiences of participants in engineering education research, it is particularly useful in cases where the voice of the participant is needed as a lens into particular phenomena and to provide a direct account of the participant.

KEYWORDS
Narrative Research, Qualitative Data Analysis, Pathway Transition Education

Introduction

The Council of Australian Governments (COAG) has set clear targets (Callan and Bowman, 2013; Bradley, Noonan, Nugent and Scales, 2008) for Australia to increase the percentage of the population entering Higher education. COAG indicated that by 2025, 40% of people aged 25 to 34 years should have a bachelor degree, up from 32% in 2008. One important approach to achieve COAG target is to improve access to Higher Education Bachelor Degrees by creating an improved post-secondary school pathways education for Vocational education graduates to gain entry into the Bachelor degree programs (Callan and Bowman, 2013; Burke and Shah, 2006; Access Economics, 2009). The importance of this target provides the need to adequately understand the academic transition the articulating students are experiencing from Pathway education to Higher education.

This paper presents the findings from a study of students lived academic transition experiences from a Pathway program into a Bachelor of Engineering (Honours) program. Narratives collected from this research provide an insight into this transition experience and a useful feedback into the development of Pathway education programs. Also, the outcomes of this study inform the education community and facilitate change in the provision of transition services.

Context and Method

The motivation for undertaking this study was based on the importance of pathways for upskilling the workforce and bringing more people into the Higher Education (HE) system that wouldn't normally have the admission opportunity from the traditional entry requirement. This is essential to the continuous growth of the modern industrial economy.

The Pathway education pedagogy represents innovation in education and training. This is the process of finding a new, an innovative method of delivering education system from the curriculum of established current education systems or practices. As an example, in Australia, at Swinburne University of Technology (SUT), first-year units from the Bachelor Degree of Engineering (Honours) were used to set up a curriculum to deliver the same units as part of an Associate Degree in Engineering. The Associate Degree is then delivered with more flexibility and allow a variety of admission entry requirements. This method of providing foundation units of Bachelor Degree allows the graduate of Associate Degree of Engineering to achieve two objectives. Namely, to gain significant credit towards a Bachelor degree program, if there is a desire to follow pathway system, and provides solid preparation for a vocational career in engineering industries as an Associate Engineer if there is a desire to exit study and get a job. However, little is known about the experiences of students taking these units in an associate degree and their subsequent pathway experiences into higher education.

Data Collection Approach

"The main claim for the use of narrative in educational research is that humans are storytelling organisms who, individually and socially, lead storied lives. The study of narrative, therefore, is the study of the ways humans experience the world." (Connelly & Clandinin, 1990, p. 2).

Higbee, Arendale, and Lundell (2005, p12) call for more qualitative research in their recommendations, arguing that it is possible to know quantitatively how a student is performing in a course based using quantitative measures such as assessment marks, grade point average, and other achievement markers. But Interviews, focus groups and classroom observations provide information about students' perceptions of their educational experiences that cannot be captured through the traditional quantitative measures. The graduates of the Associate Degree of Engineering have so much more to tell us regarding their academic transition into the Bachelor Degree (Honours).

In this study, the first set of participants (total of 6 cases) were invited to attend a first round of an in-depth interview to collect data for a narrative analysis. Narrative analysis of the transcript of the in-depth interview data for the first set of the participants was performed, and it led to a conclusion to invite a second set of participants (total of 6 cases) for another first round of an in-depth interview to increase the data set. Narrative analysis of the transcripts of the interview data for the second set of participants was performed, and the outcomes of the analysis indicated that fifty percent of all the participants need to be interviewed the second time for longitudinal information and to authenticate the narrative co-constructed from the first interview. This process provided an opportunity for the validation of the co-constructed narratives for all the first round of interviews analysis.

Four cases from the total of twelve in the major research are presented in this paper. The majority of the participants in this research have common characteristics that gave a reason to why they have chosen to do an Associate Degree in Engineering. These characteristics were (a) They enrolled into the Associate Degree to get into the Bachelor Degree of Engineering or Science study at university, (b) They obtained lower than expected Bachelor Degree entrance requirement score and (c) they had not taken the year twelve Mathematics Method unit as a prerequisite for the bachelor. Table 1 provides the data collection summary of the four cases presented in this paper.

Table 1: Data Collection Summary

2015 AD Graduates Case Name	**2016 Enrolment**	**1st Interview**	**2nd Interview**
Chris	Civil Engineering	July 2016	Oct 2016
Bobby	Robotics and Mechatronics Engineering	Oct 2016	
2014 AD Graduates Case Name	**2015 Enrolment**	**1st Interview**	**2nd Interview**
Caroline	Mechanical Engineering	Aug 2015	May 2016
Sofia	Civil Engineering	Sept 2015	Nov 2016

Outcomes of the narrative analysis

The narrative analysis method used for the collected data was described in an accompanying paper (Alao, Mann & Bryant, 2016). Where Polkinghorne criteria (Polkinghorne 1995) were used to create a setting with depth, temporal continuity using an order that easily connects the reader to the story and Mauthner & Doucet's "voice-centred" method (Mauthner & Doucet, 1998) was used as an analytic approach to the interpretation of the transcript data. This paper focuses on the findings of this analysis, and these outcomes are presented below.

Four cases were selected for presentation from the twelve investigated to demonstrate the importance of providing an individual voice to transitioning students. Any of the other twelve cases for this paper could have been selected; the four selected provide some common story plot among all the twelve cases and some individual uniqueness.

The narratives from these cases demonstrated the usefulness and reason why the Narrative inquiry method was important for our research. The personal account given by the participants and co-constructed by the research analysis could not have been possible without using a methodology that allows empathy during the data collection process.

It is equally important to know that these narratives are evidence to make a case for change. A change to either ensure that most students' lived transition experience stories indicates an improvement in their academic transition or a change to make sure that certain transition current practices do not continue. The following are some key extracts from the narrative analysis of the research data for the four selected cases:

Case One Extracts – Caroline Engineering Challenge

Caroline was not sure whether she could cope with doing engineering, but she has a desire to become an engineer. She found the transition from high school into the Associate Degree a big challenge. However, she was successful and graduated to articulate into the Bachelor Degree.

Extract 1.

Immediately she started the Associate Degree, she realised the academic challenge ahead doing engineering at a university, Caroline said, the *“first two weeks I didn’t think that I could do engineering and so I was having a bit of a meltdown to my mom. I can't-do this; I’m dropping out”.* Caroline’s mom encouraged her to continue. Then she said, “*Look at me now. So, it’s good that I stayed, but that was hard to transition from high school to university.”*

Extract 2.

Caroline said “*It was good having one, we did Fluid Mechanics while still in the Associate Degree. That was good having rather than being straight away thrown into a real university kind of set up. Having that one to ease into it was helpful”.* Doing transition unit in the second year of the Associate Degree was a positive experience for Caroline. She said it “*Just gave us a feel of what was going to be like in the Bachelor Degree and so it’s a lot easier I reckon to have that extra Fluid Mechanics that we did to ease us into a different way of learning”* in the Bachelor Degree.

Extract 3.

Caroline was happy and grateful for a good preparation received from the Associate Degree; She said “*I found in the Associate Degree I learned with people in groups, and I’m more of a solitary learner at the moment. I enjoy going through it by myself, and I learn it better by myself at the moment than I did with other people, but I think that’s because I’ve built up that knowledge in the Associate Degree”.* She was ready for the “*massive lectures with 200 plus people”.* Now in a good position to deal with a new learning environment where “*It’s harder to make friends. People that you do assignments with and work with in a big lecture theatre you don’t see those more than once or twice in the semester because you’re not sitting next to the same people every day”.*

Case Two Extracts – Sofia Engineering Adventure

Sofia was an international student with Australian born mother. She was certain about becoming an engineer and selected civil discipline even before gaining admission into the Associate Degree. This has a uniqueness of strong goal setting. Sofia was undeterred by all challenges she came across, and she completed the Associate Degree then transited into the Bachelor Degree.

Extract 1.

Sofia started her engineering adventure story in Cyprus in 2013. She started her story by saying, *“I’m originally from Cyprus, but my mum was born here, so I’ve got an Australian passport, so I’m an Australian citizen, and so I always wanted to come to Australia to study”.* She wanted to do a Bachelor Degree in Engineering, but the entrance requirement meant she would not be able to gain direct admission into the Bachelor Degree program in Australia. She said, *“I finished high school, I didn’t complete my IL program for English, and to get into the bachelor I had to complete that for one year, so I applied for the Associate Degree which gave me the opportunity to come here and start from that and then go into the Bachelor Degree. So I am really happy that I did that”.* Sofia used this reason as the basis for chosen Associate Degree as her pathway into the Bachelor Degree and said, “*I would miss a year of my life doing nothing if I did not get admission into the Associate Degree”.*

Extract 2.

She was very happy with her Associate Degree transition experience, she said*, "I will stand by my experience in the Associate Degree. So what I realised now is that I learnt the same thing as I would learn in the Bachelor Degree but in an easier way. And so I didn't miss out on anything so I don't feel I have something that would keep me back from understanding better in the Bachelor Degree",* this was assurance that she was well prepared for her transition into the Bachelor Degree. And finally, Sofia said, "*Now I have applied for the Bachelor Degree I got in from the Associate Degree there was no problem with that, so we got accepted straight away, and now my marks are really good, and I am trying so hard, and I am enjoying it".*

Case Three Extracts – Chris Big Engineering Transition

Chris was indecisive on what to do after high school. He was lucky to have a well-informed career teacher at high school, who suggested the Associate Degree of Engineering as a career path to Chris. It was difficult at the start for Chris due to the change of learning environment and getting used to a new colleague but he was happy with the decision, he successfully graduated and transferred into the Bachelor Degree.

Extract 1.

According to Chris, "*Our careers teacher at high school had a positive experience with students in previous years of the Associate Degree. He suggested to some students to do the course, and I think he must have spoken to the kids who have done it, and he said, "Look I think this is a good path for you guys to take. Maybe weren't quite ready to jump straight into the Bachelor with just our study habits, we were not quite as focused as we needed to be at that time to do the Bachelor. But the Associate Degree was an opportunity to not completely write off university and give us a chance, a stepping stone to ease us into the university experience. And so he said, "Look, guys, I think this is a good opportunity for you guys, it's attainable," because we weren't studying as hard as we needed to, to get straight into the Bachelor. We need to get 85 or more to get straight in. And he said, "I think you should consider this Swinburne's Associate Degree, it is especially good for pathways to the Bachelor."* Chris took the advice of his career teacher and applied for the Associate Degree course. He was admitted and started the first year. Chris said, *"The first year was good, there was a lot of support obviously, and it was more of a school environment as opposed to just enormous lecture theatres".*

Extract 2.

The Associate Degree was well suited for Chris due to the flexible learning environment provided for the delivery of the program. As Chris said, "*we have smaller classes, much more one-on-one time with teachers and they were a lot of communications. You guys were always there to talk to us, and we come to your office and ask questions and pester you all the time. So, it was good and so the first year was good".* Naturally expected, Chris was very worried in the semester one of the course, new environment, new mates and course. He said, *"I was a bit nervous at the start, in semester one, but then we had all the help from the teachers, and I did alright. In the second semester, I got a bit complacent, I thought and ended up failing a unit. But that was completely my fault, that wasn't anything to do with lack of resources or anything, it was just the fear from the first semester had worn off, and I thought, oh this is not bad, I've got this but then came back to bite me. And then, so first semester of the second year was similar it was good, I realised I've got to get my act together, and again that was a good semester I think I enjoyed the subjects".*

Case Four Extracts – Bobby Engineering Project Education

Bobby academic transition is about change. He was very particular about the effect of change of environment, the change of learning style from the Associate Degree to the Bachelor Degree. The expected level of responsibility was challenging for Bobby, but he was successful in his transition into the Bachelor Degree program.

Extract 1.

According to Bobby, the biggest part of his engineering adventure was the transition between the Associate Degree and the Bachelor. He said, "*Ok well there's kind of few different components to it, the biggest transition point for me, is the change of environment, the change of learning style. Alright, obviously, they come in the form of lecture, tuts and lab. They are different between the Associate Degree and the Bachelor".* He was very keen to give his comparison account between the two environments. He said, "*Ok, so the Associate Degree was obviously a very classroom oriented environment most of our day was spent in a classroom with the same teacher and the same group of people every day, and you got to know everyone which is a bit different to the Bachelor".* According to Bobby in the Bachelor degree, everyone was business-like and focused on the purpose why they are in the University. He said, *"Everybody's a bit more business oriented, you don't get to know everyone it was close-knit, and people don't get to know each other. That's a big transition, a big difference. And that also means that the material is delivered differently".* Bobby felt you know you are in Bachelor because "*you get lecture explain to you and you go to tut and get showing how to do questions, and then you go away, and you study the material on your own. Whereas in the Associate Degree, you get all of that in the one setting; In one class, you have the material explained to you, the questions explained, and then you get an opportunity to do it yourself with a supervisor and to correct you if you make any mistakes, which I think is a really good thing about the Associate Degree. It is quite reminiscent of high school".* Bobby was appreciative of the Associate Degree learning environment and said: "*It's difficult to say because the classroom environment that I was describing before is really helpful and I found it easier to get better marks".*

Extract 2.

Bachelor Degree expected more responsibility from the students beyond what was offered in the transition elective because students are expected to make a decision on their subjects' choices and do a self-allocation into teaching activities. This responsibility was challenging for Bobby. He said, "*And then when you get to the Bachelor, you end up having to pick and choose the subjects that you do by yourself. And that was something that was a little bit awkward I think, I didn't know what subjects were going to be important and which ones I should do first and that kind of thing; I didn't know a lot about the course moving into it".* A transition course adviser would have been helpful to explain and assist the graduate of the Associate Degree articulating into the Bachelor. According to Bobby, "*Well When I was choosing my subjects I wasn't sure how the system worked and so what I did was called the Student help desk. I asked them to explain what to do, but they were very casual about it, they were kind of if you can do it just sign up for it if the prerequisite is not there then don't do it. It's like ok sure, and I had a looked at the unit outline that described the subject. And even from that, it's hard to tell what's going to be good what's going to be bad. In retrospective, it probably would have been being good to come in and maybe talk to somebody who was a course adviser or something like that I would have been pretty beneficial, and I might have avoided that situation".*

Findings & Discussion

The findings from this research are useful feedback information into the academic transition of the graduates of the Associate Degree. The following are the findings from the four cases presented in this paper. Some of these findings are described as follows.

Caroline: Key findings from the narrative

1. Doubt of their ability to do engineering study.
2. Encouragement from family stopped them dropping out of Associate Degree.
3. Doing Fluid Mechanics as a transition unit (from the Bachelor) was a positive academic transition practice.

4. Associate Degree provided good preparation for transition into the Bachelor through a built up of good foundation knowledge.
5. Hard to make friends and form learning group in the Bachelor program.

Sofia: Key findings from the narrative

1. Admission flexibility (skip one year of IL English course) as the basis for chosen Associate Degree as a pathway into the Bachelor Degree.
2. Learnt the same foundation units as in the Bachelor Degree but in an easier way.
3. Associate Degree offered good transition preparation for the Bachelor- I didn't miss out on anything, so I don't feel I have something that would keep me back from understanding better in the Bachelor Degree

Chris: Key findings from the narrative

1. Career teacher suggested Associate Degree as a pathway into the Bachelor- Our careers teacher at high school had a positive experience with students in previous years of the Associate Degree
2. High VCE score as admission requirement into the Bachelor was one of the reasons for choosing to do the Associate Degree.
3. In the Associate Degree, the first year was good, there was a lot of support, and it was more of a high school environment as opposed to just enormous lecture theatres.
4. Nervous at the start, in semester one of the first year, but then he had all the help from the teachers, and did alright.

Bobby: Key findings from the narrative

1. The biggest transition point for Bobby, was the change of environment, the change of learning style from the Associate Degree to the Bachelor Degree.
2. Everybody's a bit more business oriented, you don't get to know everyone it was close-knit, and people don't get to know each other. That's a big transition, a big difference.
3. The learning material is delivered differently between the two programs. Associate Degree delivery is quite reminiscent of high school.
4. In Bachelor, you end up having to pick and choose the subjects that you do by yourself. And that was something that was a little bit awkward and challenging.
5. It would have been being good to come in and maybe talk to somebody who was a course adviser.

The following discussion of the above findings provides a case for change that is supported by the evidence from the narratives from the voices of the participants.

The academic transition provided in the Associate Degree program where the Associate Degree students are required to select a one-unit elective from the Bachelor Degree program was a good transition service provided by the university. The Associate Degree graduates considered this as important for their academic transition. In the four cases presented above, these participants did either Fluid Mechanics or Programming for their transition elective. They claimed that it was useful for their transition. Further research is required to find out if doing more than one elective unit would be beneficial to the transition of the Associate Degree students or not.

The Associate Degree graduates highly rated the supportive environment provided by the program. In this study, the participants cited the peer-to-peer support from their colleagues and a small student's classroom size assisted their success in the program. The open access and support from the Associate Degree teachers were invaluable to the students of the program.

There was a call for a course specialist adviser that understand both the vocational education and higher education environments to provide initial transition interview with graduates of Associate Degree articulating into the Bachelor Degree student and advise on study plan and timetable issues.

The students are expected to develop their own ability to navigate their transition after graduation from the Pathway program and plan their units' selection and learning strategies using the resources and information provided by the university. This was considered as important to the students self-depend and development in a university.

We can argue the need for the following changes from the above discussion. These changes would significantly improve the transition experience of the graduates from the Associate Degree articulating into the Bachelor Degree:

The graduates of the Associate Degree agreed upon the importance of doing transition unit as part of the Associate Degree program as a preparation for the Bachelor Degree learning environment. This is a positive transition experience gained by these graduates, and this initiative should be expanded to allow the students to do more than one Bachelor Degree unit as electives during the second year of their Associate Degree program.

An introduction of a course adviser specialist to talk to the articulating students through their transition study plan for the Bachelor and timetable requirements. This may require an academic with an experience in the vocational and higher education teaching environment to assist the professional staff to conduct a pre-enrolment interview during the orientation period.

Goal setting is a primary tool required by students in any pedagogic education environment. It is argued that the art of goal setting is a skill that should be taught in Higher education to the transition students from developmental pathway education. The graduates of Associate Degree are coming from the VET environment where the teachers are performing the task of goal setting and planning their learning strategies for them. Further study needs to be done to gather evidence on what support is available to the transition students, to assist them in developing their skills in learning strategy planning, since this is the key to their academic success in the higher education environment as suggested in Dowling, D. (2010) & Australian Workforce Productivity Agency (2012) report.

Conclusions

Narratives from the Narrative analysis offers a different way of collecting feedback and analysing the lived transition experiences of participants in engineering education research, it is useful in cases where the voice of the participant is needed as a lens into particular phenomena and to provide a direct account of the participant.

The findings of this research of the Associate Degree graduates telling their lived academic transition experience would be used to argue for changes to the transition services provided for these graduates moving to the Bachelor Degree programs and to inform the engineering education community on the provision of transition services requirements coming from the voices of these graduates in Australia.

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The Emerging Suite of Virtual Work Integrated Learning Modules for Engineering Students

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SESSION S1:

Is Integrated Engineering Education Necessary?

CONTEXT

Students of accredited engineering programs in Australia must engage with practice. In most universities in the country this has been achieved through placements of at least 12 weeks. It is becoming increasingly difficult for students to secure these opportunities and consequently universities must complement placements with other opportunities.

PURPOSE

We identified the requirements and learning outcomes to design a suite of virtual work integrated learning modules to complement opportunities for engineering students to engage with professional engineering practice. The modules are virtual in the sense that they provide electronic interaction with real and/or simulated practitioners, and access to workplaces using virtual reality and other simulations. We outline the planning and the suite of modules.

APPROACH

Descriptions of four hypothetical modules were developed. Engineers, university staff members, Engineers Australia staff members, and engineering students reviewed the modules at workshops in Melbourne, Perth and Brisbane. Responses to the modules were analysed to identify the important stakeholder requirements and also potential solutions to meet these. The suite is currently being developed and tested. Discussion or workshops were also held at the Australasian Association for Engineering Education 2016, and meetings of the Australian Council of Engineering Deans, Associate Deans Teaching and Learning, and the Australian Council of Deans of ICT.

RESULTS

Key requirements are that modules must include disruption and uncertainty, and support structured progression from first to final year. The suite should include some modules that can be integrated into credit-bearing units in addition to modules that stand-alone.

Learning outcomes include professional elements of the Stage 1 Competences, especially those related to decision making and ethical responsibilities; items to support motivation and skills for students to become self-directed learners; and items to support career literacy.

CONCLUSIONS

A suite is being developed including: modules to be adapted for integrating in first, second, and third year units; and more authentic modules in which senior students will work in groups on authentic engineering tasks such as tendering with electronic meetings with engineers.

KEYWORDS

Work integrated learning, virtual reality, practicum

Introduction

Students of accredited engineering programs in Australia must engage with practice. In most universities in the country this has been achieved through placements of 12 weeks or longer, and these placements have been reported by students to support them in developing competencies and to increase their motivation towards becoming engineers (King & Male, 2014; Male, 2015). Kinash and Crane (2015) found that the most important strategy to improve graduate employability is participation in well-managed work experience and placements.

Unfortunately it has become difficult for students to secure placements. Consequently universities must complement workplace experience with other opportunities for engaging with practice. Several projects have developed immersive environments and shown that these support students' learning (Cameron et al., 2009; Savage, McGrath, McIntyre, & Wegener, 2010; Shallcross, Maynard, & Dalvean, 2011). Smith, Ferns, Russell, and Cretchley (2014) recommended future research into simulated work integrated learning.

We are developing a suite of learning modules to complement existing opportunities for engineering students to engage with professional engineering practice. The modules provide electronic interaction with real practitioners, and/or simulated practitioners, and access to workplaces using virtual reality and other simulations. We are working with Engineers Australia to develop a pool of engineering mentors to interact electronically with students in the learning modules. Students from universities across Australia should be able to undertake the modules.

This paper reports on the planning phase in which the learning outcomes and requirements for the modules were developed, and outlines the planned suite of modules.

Principal requirements

Principal requirements for the modules were based on literature and the goals of the project. The first requirement was that modules should be consistent with the accreditation requirement that students engage with engineering practice (Engineers Australia, 2011). Beyond this, we began with learning outcomes, consistent with the curriculum development principle of constructive alignment (Biggs, 1999).

Learning outcomes

1. Learning modules in the suite should contribute to students developing the learning outcomes consistent with the Stage 1 Competency Standards (Engineers Australia, 2011, p. 2), which are central to program accreditation criteria, and include: "1. Knowledge and skills", "2. Engineering application ability" and "3. Professional and personal attributes".
2. Generic engineering capabilities that are most difficult to achieve without work integrated learning should be included among learning outcomes for the suite of modules. Examples are capabilities to take account of contextual factors such as environmental, financial and social issues, to take account of practical issues such as constructability and maintainability, and to function effectively in a workplace.
3. Some of the modules should support students to develop career literacy, meaning capability to secure or create employment and develop a career.

Learning activities

4. Learning activities in the modules should be authentic, meaning that students engage in tasks that are part of engineering practice.
5. In the modules, students should interact with real engineers, to enhance authenticity and support identity formation and motivation as student engineers. Engineers spend

60% to 80% of their time in collaborative work (Trevelyan, 2014). Although geographically disparate, it was planned that students undertaking the learning modules would spend much of their time interacting with each other and with real engineers. Students should use authentic digital communication methods as might be used by engineers.

6. In the modules, students should use authentic engineering processes for managing systems and for approaching tasks, such as minute-taking resources developed by (Foley, Gill, Senadji, Palmer, & Martinez-Marroquin, 2017).
7. In the modules, students should actively participate in interactive teams, with cycles of individual and group reflection, and feedback from professional engineers, consistent with recommendations for work integrated learning (Cooper, Orrell, & Bowden, 2010).
8. In the modules, students should be supported to develop inclusive learning communities (Wenger, 1998), especially for female students who are under-represented in engineering.
9. To be inclusive, the modules should be designed such that participating students and engineers need no more equipment than are commonly available to students in Australian universities.

Method

Workshops were held with stakeholders in order to refine the requirements to meet their needs. One-page descriptions of hypothetical modules were developed for review based on the principal requirements. The modules involved (A) a decommissioning process, (B) competing to win a tender, (C) planning a maintenance event, or a root cause analysis for a safety incident or a failure and (D) working with others.

Each module description included

- learning outcomes
- year level of students for whom the module would be designed
- whether the module would be stand-alone, or integrated into a relevant unit
- duration
- learning activities
- any interaction with a virtual environment
- how students would interact with engineers
- how and with whom students would reflect on their learning, and
- assessment mechanisms.

In modules A and B, students would be given a period of weeks to work in a student team on a task presented to them by a senior engineer, and with the opportunity to interact electronically with a junior engineer during the task. Module C would be integrated into a relevant unit. Students would visit a virtual site and work together on a task for which practical features of the site are important. In Module D students would communicate with others in a simulated workplace. They would try to complete tasks that require them to make decisions about how to communicate with other students who have competing priorities.

Engineers, university staff members, Engineers Australia staff members, engineering students, and a senior recruitment manager in an engineering company, participated in workshops in Melbourne, Perth and Brisbane ($N = 43$). At the workshops, groups of participants each reviewed two modules, and addressed the following questions:

1. How can you see this working, if at all?
2. What are its strengths?
3. What concerns would you have about it?
4. How could it be improved?
5. How does this compare with anything similar that you are aware of? Can either benefit from the other?
6. Any other comments?

Participants recorded hand-written group responses. Audio recordings and notes were also made during group reports and plenary discussion among participants. The workshops were three hours long including light refreshments. The recordings were transcribed.

Participants' responses to the modules were analysed to identify the important stakeholder requirements and also potential solutions to meet these. Minor revisions to modules were made between workshops to improve the alignment with stakeholders' needs and recommendations.

Discussion or workshops were also held at the Australasian Association for Engineering Education 2016 (N = 25), and meetings of the Australian Council of Engineering Deans, Associate Deans Teaching and Learning, and the Australian Council of Deans of ICT.

Findings, Discussion and Further Research

Responses were generally enthusiastic. Participants noted that working in geographically disparate locations is common in engineering practice. Engineers noted that many of the activities supported learning that was important and yet often received insufficient if any attention in engineering programs.

Feasibility of recruiting engineers

Many stakeholders were concerned that it might be a challenge to recruit enough engineers to interact with students, and they recommended use of videos and other mechanisms as a backup plan. The first version of Module D involved interaction with engineers who were uncooperative. However it was noted that employers would not wish to risk their reputations but engaging in frustrating behaviour – however authentic. A possible solution to this problem is to use simulations. Students could reflect with a real engineer after completing an activity using a simulation.

Structure of the suite of modules

University staff members recommended structured progression in the learning modules from first to final year with increasing authenticity, autonomy, and responsibility in the activities and assessments. University staff members also suggested designing modules in which senior students supported junior students. Students responded positively to this suggestion.

Participants agreed it would be beneficial to learning if students from multiple universities collaborated in each module. However, university staff members recommended starting trials with students from only one university at a time participating in any module, to simplify the first trials and maintain credibility.

Authentic learning activities

University staff members and engineers were adamant that students should experience disruption and frustration in the modules, rather than the controlled environment more common on campus. Disruptions, or unexpected changes, are common in practice. Although unfamiliar with the protocol, participants responded positively to our suggestion to use Professional Performance Innovation and Risk (Warren Centre) as a process that would be encouraged or expected in many modules in order to perform professionally.

Participants felt that it was important that students feel emotions such as anxiety in order to learn. Some participants described important experiences interacting with non-engineering members of teams. They recommended that students should learn to see the perspectives of workers with practical experience, who often perform physically demanding jobs, and with whom engineers are likely to interact in practice.

Practical, financial, and social capabilities were identified by participants as being difficult to teach or overlooked in traditional curricula. Engineers recommended that learning about safe and ethical decision-making and practice should be integrated into learning activities that are not primarily about these capabilities.

Assessment

All groups of stakeholders reported that assessment of learning is an essential feature of the modules. University staff and students recommended providing flexible modules and assessment mechanisms that could be adapted for the diverse needs of universities. Consistent with this requirement, the learning activities and assessment should be sufficiently open that they can be used multiple times without students being able to copy the work of previous students in order to complete the activities and assessments.

Revised learning outcomes

The learning outcomes and other requirements were revised to those listed below. Students who complete the modules should demonstrate:

1. development contributing to achievement of Stage 1 Competencies
2. capability and attributes for self-directed learning
    - understanding of engineering roles and value of engineering
    - motivation towards engineering studies
    - self-efficacy for working as an engineer
    - an identity as a student engineer
    - ownership of responsibility for learning
3. career literacy
    - improved capability to secure or create engineering work
    - understanding of the employment market in the student's discipline
    - capability to plan navigation of the employment market including lifelong learning, and
    - an expanded engineering network.

Requirements for every learning module

Every learning module should:

4. contribute to engaging with practice for accreditation purposes
5. support at least one of the intended learning outcomes
6. be assessed with mechanisms that can be adapted for different universities
7. be inclusive
8. support students to receive feedback and reflect on their learning
    a. in notebooks or portfolios
    b. with peers and/or engineers
9. be suitable for use year after year
10. be robust to difficulties recruiting engineering mentors and
11. have evaluation processes.

Requirements for the complete suite of learning modules

The suite of learning modules should:

12. include realistic disruption and uncertainty
13. be structured with progression from first to final year with increasing authenticity and autonomy
14. support development of sociotechnical learning outcomes including capabilities to practise ethically, safely and sustainably
15. support financial learning outcomes
16. develop practical engineering skills
17. use authentic engineering processes
18. use Professional Performance
19. include modules within units, and include stand-alone modules
20. be suitable for use in one or more universities concurrently and
21. support senior students to guide junior students.

Future research

The modules in Table 1 are being developed.

Table 1: Planned modules

Module ID	*Main learning activity*	*Proximity to workplace/practitioners*	*Implementation*	*Year-level*
I	applying for engineering jobs	electronic interviews of and with engineers	integrated	1, 4, 5
II	communication/ self-management in authentic engineering scenarios	simulated workplaces and reflection electronically with team and engineer	integrated	1, 2, 3
III	safety in design exercises based on real cases	virtual site, and electronic meetings with students and engineers	integrated	2, 3, 4
IV			integrated or stand-alone	2, 3, 4
V	preparing a tender		stand-alone	3, 4, 5
VI	evaluating a tender		stand-alone	3, 4, 5
VII	pump isolation for maintenance		integrated or stand-alone	3, 4, 5
VIII	hazard and operability meeting meeting	Simulation, and electronic interaction with engineers	integrated or stand-alone	4, 5

Conclusions

A fortunate consequence of the problem that engineering student placements in workplaces have become scarce is that educators are being forced to become innovative about integrating engagement with practice within engineering curricula. As a consequence students are likely to benefit from structured engagement with practice throughout the curriculum from first to final year, with strong scaffolding at the start and increasing responsibility, autonomy, and authenticity in the learning activities for students as they progress towards graduation.

This project aims to support educators in embedding engagement with practice from first year; providing capstone, authentic, learning opportunities; and developing a sustainable pool of engineering mentors.

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Long term study of attendance rates in a civil engineering unit of study

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SESSION: C1: Integration of theory and practice in the learning and teaching process

CONTEXT: The author has been collecting attendance lecture and tutorial data in a 2nd year civil engineering core unit of study for nearly 15 years. The paper investigates any correlation between performance and attendance, and also seeks to consider the impact of international status and previous results. The timeframe of the study intersects with the introduction of lecture recording, and will seek to investigate if there is any noticeable impact on attendance caused by that technology.

PURPOSE: This paper will provide long term data on student attendance rates and examine possible correlation with technology introduction and student performance.

APPROACH: Attendance data over many years has been taken via the setting and collection of (on average) 9 non-assessable formative tasks in random lectures during a typical semester (3 lectures a week × 13 weeks) for over 15 years. It is also possible to correlate that data (in selected year) with student demographics. Individual lecture recording usage was obtained from the analytics of the Lectopia or Echo360 software. Lecture recording commenced mid way through the collection period, so it is possible to assess the impact of that technology.)

RESULTS & CONCLUSIONS: The main observations appear to be consistent with findings of similar much shorter term studies, but the added strength of spanning 16 years. There has been slow and steady decline in lecture attendance, with no evidence of changed rate of declined cause by the introduction of lecture recordings. The decline in average live attendance appears to be caused by increasing cohort who attend a minimal number of lectures, rather than the entire cohort attending slightly less. Only a small percentage of low attending students make significant use of recordings.

KEYWORDS Attendance, lecture recording, student demographics

Introduction

Anecdotally, the introduction and increased usage of lecture recordings at university causes concern in teaching staff will not get the full details of a topic, lose the opportunity to ask questions, and increase surface learning if students cram an entire course by watching an entire semester of lectures in the final week. There have been many studies on student attendance, but most are short term snapshots on 1 year only. This paper reports on attendance data spanning 16 years and including the introduction of lecture recording technology, and is able to link at individual student level relationships between live and recording lecture attendance or viewing.

Previous studies, research and data on attendance rates

Since the introduction of electronic media for educational purposes, there have been many studies on the impact on attendance, and relationship with marks. It is not the intent of this paper to provide a comprehensive literature review.

A number of papers provide analysis of multiple studies. For example:

- Gyspers et al (2011) examined other studies from 2004-2010, observing “Whilst some studies report reductions in attendance of 10-33% …., the majority have found no difference in attendance pre- and post-WBLTs [web based learning technologies]. Indeed, most students who make extensive use of WBLTs also attend lectures.”
- Kinash et al (2015) studied 30 papers between 2007 – 2012, with some key observations such as “the evidence is compelling in that there is significant agreement between multiple studies that students who have access to online lectures will continue to come to class.” and “some studies have produced empirical support for the argument that students who attend lectures achieve higher grades, this is contradicted by a number of other studies.”

Most individual studies are either survey based, or make use of limited and shorter term analytic data from learning management systems, but usually do not have the specific data to link lecture attendance, on-line video usage and marks at individual student level, eg:

- Yeung et al (2015) reported on a single year in a big first year unit of study observing “Non-frequent attendees were more likely not to use lecture recordings (48.1%) to make up a missed lecture than frequent attendees (34.3%).”
- Panther et al (2012) is an example of a more qualitative, self selected survey group focusing on how students used resources rather than whether they were used at all, observing. “Students who are able to attend face-to-face lectures identify the intangible experience of the live lecture as important, including the potential for interactions in real time and space.”

However, the current author has not yet been able to find studies on attendance rates over an extended period that cover pre and post lecture recording era, and can link individual student data on live and recorded lecture attendance or viewing.

About the unit of study

General

The unit of study is CIVL2201 Structural Mechanics taught at The University of Sydney. It is a 2nd year compulsory unit for undergraduate students in civil engineering. Since 2009, a small number of postgraduate students in a professional masters degree have enrolled in this unit. They represent a small number of students (approximately 6% in 2017). Since 2013, a small number of non-engineering students doing an undergraduate degree in project management have enrolled in this unit. They represent a small number of the total cohort (approximately 5% in 2017).

The unit of study has had the same (sole) lecturer/coordinator since 2001. There are 3 ×1 hour lectures and 1 × 2 hour tutorial per week for 13 weeks.

Syllabus

The syllabus is fairly typical of any engineering subject called "Strength of Materials", 'Mechanics of Solids" or "Structural Mechanics". Specific content includes simple bending moment diagrams of determinate beams, stress and strain under axial force, bending moment, shear and torsion, beam deflections and buckling.

The pre-requisite is a unit in fundamental statics (force and moment equilibrium of 2D and 3D bodies under forces and moments). The derivation of theory makes limited use of first year university mathematical content (eg PDEs or matrices) but use or mastery of such content is barely required for assessment tasks nor an issue that would impact a student's ability to pass. A sound and competent knowledge of high school maths (eg trigonometry, single variable calculus, quadratics and cubics, physical units) is seen as critical pre-requisite knowledge.

Teaching style

At least initially the unit might be classified as a typical "chalk and talk" subject. The teaching mode was more traditional, using overhead projection with gaps in the notes that were filled in during class. Over the years, the mode has approached more of what is perceived as the "flipped classroom" with much more emphasis during lecture time on asking and answering "why", and trying to convey structural engineering concepts qualitatively, rather than quantitatively. There is substantial use of live props (which are not recorded), and computer animations (which students can download). The lecture recording process does not provide a good replacement for the lecture experience (in the humble opinion of the author). The unit of study is usually in the top 2 or 3 across the faculty in student surveys for large units with enrolments over 100 students.

Demographics

Table 1 shows the year by year demographic distribution of students. Total enrolments have almost quadrupled over a 10 year period from 2002 to 2012 and remained reasonably stable since. Enrolment numbers are slightly skewed due to a fairly consistent failure rate of about 30%, and taking into account students who drop out, about 20% of enrolments are repeat students. Female enrolments remained steady from 2002-2010 at approximately 17%, but there has been a very encouraging increase in female participation from 2010 to 2017 to nearly 30%.

In the last 7 years there has been a consistent increase in international students, with about half of the 2017 class being international. For the sake of simplicity, Australian permanent residents were classed as "international" on the assumption that they had arrived in Australia only "recently" prior to enrolment. They represent a small number (3 % in 2017). Mainland Chinese nationals represent about 85% of the international student body and therefore NESB. Other internationals originate from English speaking or English schooled countries such as New Zealand, India or Singapore.

Table 1: Year by year demographic distribution

Year	Total Students	Female %	International %	Lecture Attendance %
2002	100	17%	5%	57%
2003	116	17%	20%	63%
2004	127	17%	20%	69%
2005	158	17%	26%	60%
2006	193	15%	22%	52%
2007	216	14%	21%	68%
2008	239	17%	21%	61%
2009	261	18%	18%	64%
2010	288	19%	23%	52%
2011	368	23%	31%	55%
2012	373	25%	37%	57%
2013	351	21%	33%	57%
2014	358	21%	37%	63%
2015	395	24%	41%	52%
2016	425	26%	43%	54%
2017	358	29%	55%	42%

Data

Lecture attendance

Lecture attendance was logged through the submission of (non assessable) formative tasks during lectures. While teaching a new concept, students would be asked to do a quick sample question (approximately 10-15 minutes). The question is designed to be simple, and a student is encouraged to follow the format and process of an example done just prior with only minor modification to the working provided in class. Students submitted their answer at the end of the class, and submissions were logged.

Attendance for a given year is reported as a single percentage value, namely the total number of submissions divide by {the number of students × the number of tasks}. In the first year of the study (2002), the number of tasks was 4. From 2003-2017 the number of tasks per semester varied from 8 to 13, with the average number per year being 9. The first task is usually in Week 2 of the semester. Anecdotal observation is that there a number of students who attend the very first lecture in week 1, and then are subsequently absent. Such a student is classed as having “zero attendance”. Tasks are on random days during the week, so individual student data ought not be influenced by systemic issues such as a clash or a work commitment on a single day of the week.

There is some scope for error in the attendance data. Some students submitted multiple forms in class with the names of absent colleagues (under the mistaken assumption that these submissions were worth marks or influence final grade). During post semester interviews with failing students, when asked about low attendance, some students have claimed “I was there, but I just forgot to put in the piece of paper”. It is believed any impact of such uncertainties is small and unlikely to change year by year trends.

The author of this paper believes this process of attendance is a point of difference to some previous studies, which have relied on self selection and honesty by a student in a survey response. Since the attendance data is at individual student level, it then can be directly compared to other specific data.

Lecture Recording Usage

The University of Sydney first trialled lecture recording in Semester 2 2008 with the Lectopia system. This unit of study volunteered as an "early adopter" of the system in Semester 1 2009, and has used it ever since. The Lectopia system was superceded by Echo360 in 2014. Until 2014, use of video recording was voluntary, but university policy changed in 2015 for all lectures to be recorded.

Lecture recording records the lecturer's voice, and whatever is being displayed through the projector system (usually in built PC, the lecturer's laptop, or the electronic visualizer). The system does not record the live lecture experience (that is the lecturer themselves nor their actions), not any writing on a non-electronic medium (whiteboard or chalk). The lecturer for this unit does make use of non-electronic teaching resources in class that are not captured. There are also substantial lecture notes and tutorial questions and solutions, and it is likely many students rely solely on those resources rather than some combination of live or recorded lectures.

Both Lectopia and Echo360 provided student usage data in the form of the total number of separate videos "watched" by each student. There is uncertainty in this data:

- Echo360 reports usage data on mobile devices may not be logged correctly.
- There is no information on how long a student watched one particular lecture.

Results and discussion

Attendance Rates

Table 1 gives the attendance rate of 4327 students by year over a 16 year period from 2002 to 2017. The data is broken down on a year by year basis by gender (Figure 1) or international status (Figure 2). Figure 3 gives attendance rate distributions (in 10 % blocks) over 3 spread out years.

Key observations from this data are:

- There has been a gradual, and reasonably consistent decline in lecture attendance. The regression trend slope is almost identical for the entire cohort, or subgroups (male, female, international or local).
- Individual year attendance rates can be influenced by external factors. For example, 2010 had one of the largest year to year drops in attendance. This was the one and only year in 16 years that lecture times were at 9 am instead of 10 am.
- Female attendance rates are about 6% higher than for males.
- Local student attendance rates are about 4% higher than for international students.
- While not shown, attendance rates for repeating students were about half that of "first timers".
- Lecture recording was introduced in 2009 for this unit, and became compulsory for all units in the university in 2015. There is no evidence of a sudden drop in attendance on a year by year basis, nor a sharper linear regression associated with the introduction of lecture recording.
- Since attendance rates have dropped, clearly the histogram data (Figure 3) will show drops in higher attendance rate bands and increases in lower attendance rates bands. Looking more closely, the shift is caused more by a notable increase a subset of students significantly reducing their attendance, rather than most students slightly dropping their attendance. There is quite a substantial cohort (19% of first timers) attending zero lectures in 2017, whereas that cohort was non-existent in 2012.

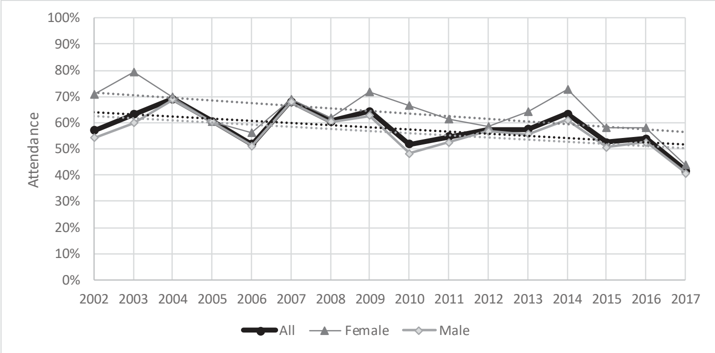

Figure 1: Year by year attendance rate by gender

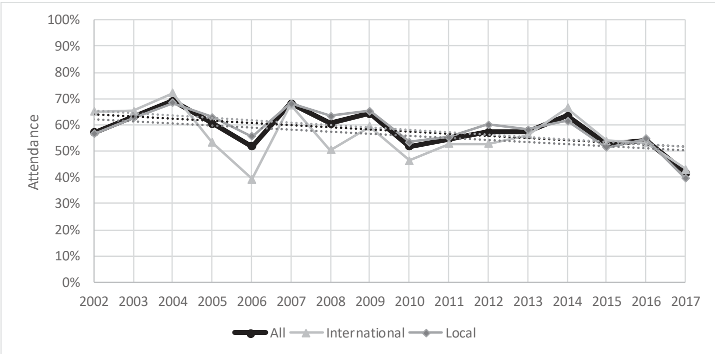

Figure 2: Year by year attendance rate by international status

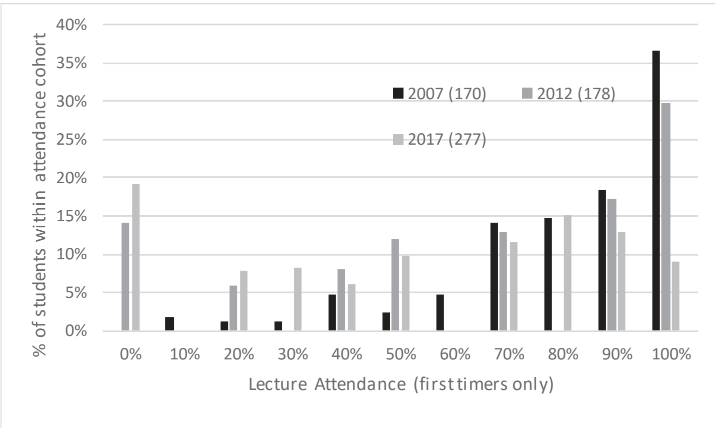

Figure 3: Attendance distribution (first timers only) in selected years

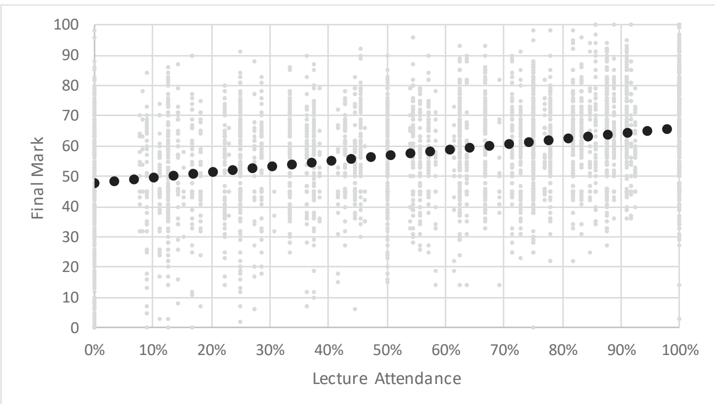

Figure 4: Lecture attendance vs final mark (2002 - 2017 aggregated data – 4327 students)

Figure 4 gives the distribution of lecture attendance vs marks across the 16 years of the study. There is significant scatter of results but there is some level of correlation (r = 0.36). One must be mindful that "correlation does not indicate causation", and hence attendance *per se* is not the factor that ensures good final grades. However, reasonably common factors in both attendance and performance are motivation and engagement (Massington and Herrington 2006).

Lecture recording usage

As mentioned above, lecture recordings were introduced in 2009. There is no evidence of a sudden drop in attendance on a year by year basis, nor a sharper linear regression associated with the introduction of lecture recording.

However, lecture recordings does cause much anecdotal concerns amongst teaching staff, most frequently along the lines of "if they watch online, they won't get the full nuanced experience of attendance and cannot ask questions." If anything, the presence of recordings can allow keen (or confused) students to replay certain segments of a lecture.

Figures 5 and 6 have mapped lecture attendance and recording usage at an individual level. The key observations from this data are:

- From 2009-2016, approximately 60% of students in a given year watched at least one recording. In 2017 this jumped to 75%.
- From 2009-2016, the number of students in each year who watched more than 50% of lectures was low – each year ranging from 1 % - 6 %. There was a notable jump in 2017 when 12 % watched at least half the lectures.
- Very few students watch (nearly) every lecture – only 1.5% had lecture watching of 90% of higher.
- It is rare for non-lecture attending students to watch a large number of recordings. Half of the (first attempt) zero attendees watched 10% or less of online recordings.
- It is very rare for high attending students to watch many videos (eg only 5% of 100% attendees watch more than 30% of videos), but students with good attendance are still watching some videos (eg 20 % of the students with at least 60% lecture attendance watch at least 10% of the videos).

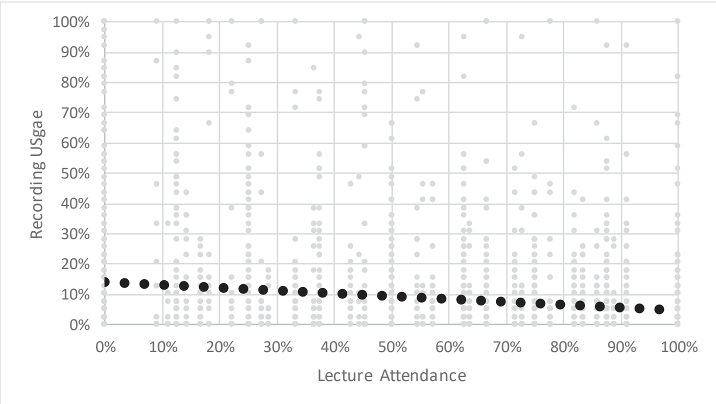

Figure 5: Lecture attendance vs recording usage (2009 - 2017 aggregated data – 2786 students)

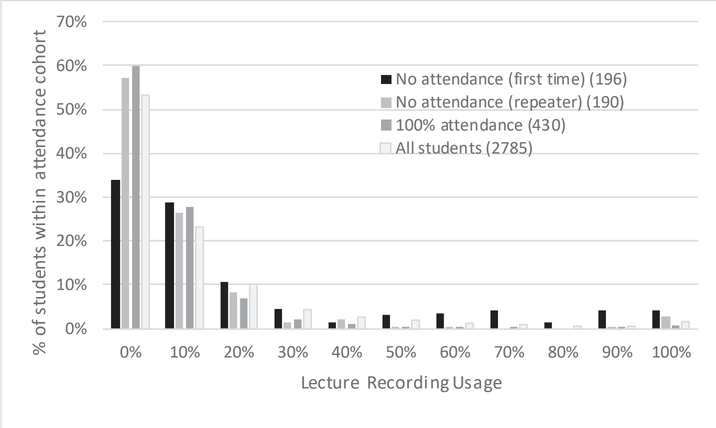

Figure 6: Distribution of lecture recording usage for various attendance cohorts (2009 - 2017 aggregated data – 2786 students)

Conclusions

This paper has presented long term data linking individual student lecture attendance, recorded lecture viewing, and marks. The main observations appear to be consistent with findings of similar much shorter term studies, but the added strength of spanning 16 years. This paper, combined with others on attendance, can aid other teaching staff in making decisions around assessment and teaching methods from the following points:

- There has been slow and steady decline in lecture attendance, with no evidence of changed rate of decline cause by the introduction of lecture recordings.
- Only a small percentage of low attending students make significant use of recordings.
- The decline appears to be characterised by increasing percentage who attend a minimal number of lectures, rather than the entire cohort attending slightly less.
- Given other studies show student comments about the benefits of being to revise or catch up on missed content, this author concludes that lecture recordings alone are not a cause of reduced live attendance rates, and that an engaged value added lecture is the best approach for maintaining student interest.

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Evaluating Humanitarian Engineering Education Initiatives: A Scoping Review of Literature

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CONTEXT Humanitarian Engineering (HumEng) is a rapidly emerging discipline in Australian and worldwide engineering education curriculum. While many engineering courses have been incorporating international service-learning pedagogy, it is only in the recent decade that engineering schools have started offering degrees in HumEng and this trend seems to be increasing. Among the many challenges that engineering schools face, major efforts will be focused on evaluating the outcomes of these new degrees and HumEng learning interventions across the engineering curriculum.

PURPOSE The goal of this study is to develop a preliminary understanding of the evaluation strategies and outcomes that have been used to evaluate existing HumEng curricular or co-curricular initiatives.

APPROACH As a starting point, we focused our search on studies published in the *International Journal of Service-Learning in Engineering* (IJSLE), which has been the main outlet for research focused on international service-learning in the past decades. From IJSLE, we identified over 40 peer-reviewed articles that reported evaluation of HumEng and similar programs. We analysed the collected articles using a qualitative content analysis approach, with a focus on what outcomes the studies assessed and what instruments were used.

RESULTS The results of the content analysis showed that two mains aspects have been evaluated in these studies: students' satisfaction with the courses/programs and development of competencies. In terms of students' satisfaction, the studies reported that students tend to see more value in HumEng and similar initiatives as compared to traditional courses. In terms of competencies, the studies have assessed numerous technical and professional skills, usually finding that HumEng and similar initiatives are effective in supporting the development of such competencies. However, the analysis revealed several limitations associated with the evaluation procedures used in the studies.

CONCLUSIONS This preliminary review showed that HumEng offer many benefits to students especially in terms of their professional development and the enhancement of competencies highly desired by industry. Our analysis also identified many potential gaps in the literature, including scarcity of rigorously validated instruments to evaluate learning outcomes, lack of focus on impact of initiatives on students' identity and career choices, and community partner's perspectives. Consequently, we conclude the study suggesting ideas for future research projects and recommendations for evaluating HumEng programs.

KEYWORDS Humanitarian Engineering, Service-Learning, Evaluation, Literature Review.

Introduction

Humanitarian Engineering (HumEng), global and local service learning, and similar courses, programs, and educational initiatives have been becoming increasingly popular in engineering education courses worldwide. These trends started with the creation of engineers without borders (EWB) chapters, the first being in France (Paye, 2010), and expanded rapidly. In 2003, EWB-International was created as a network that connects 41 national member organizations (Lucena and Schneider, 2008) and many others have been established since. In the past decades, HumEng has also moved from extra-curricular activity to become the subject of a higher education engineering degree. The first institution providing degrees in HumEng were in USA, with the first one probably the minor in Humanitarian Engineering at Colorado School of Mines established in 2003.

In Australiasia, the main focus on humanitarian engineering has been driven by the educational efforts of EWB-Australia, which have offered multiple educational initiatives for many years. Building on these initiatives, Australasian engineering schools have started offering courses focused on humanitarian engineering and the first degree in Humanitarian Engineering was open in 2017 at the University of Sydney (University of Sydney, 2016). UoSydney however is only the first institution among many that are starting to offer degrees in HumEng.

Among the many challenges that engineering schools will face, major efforts will be focused on evaluating the outcomes of these new degrees and HumEng learning interventions across the engineering curriculum. To start brainstorming ways of addressing this challenge, we reviewed literature that has been published in the International Journal of Service Learning in Engineering (IJSLE), the main outlet for local and global service learning research. Specifically, we asked the following research questions:

1. What was the focus (e.g., students' satisfaction, skill development, etc.) of the evaluation?
2. What methods were used to perform the evaluation?
3. What was the quality of the quality of the procedures used for the evaluation?

Methods

To obtain preliminary answers to our research questions, we undertook a "scoping review" of literature (Grant & Booth, 2009). As explained by Grant and Booth (2009), a scoping review provides a preliminary assessment of the available literature on a chosen topic and shares "characteristics of the systematic review in attempting to be systematic, transparent and replicable" (p. 101). Therefore, a scoping review was especially appropriate in the case of this study as our goal was to develop a preliminary picture of previous efforts to evaluate HumEng and similar learning experiences.

Data collection

For this paper, we chose to focus on the International Journal of Service Learning in Engineering (IJSLE) because it has been the main outlet for research publication on HumEngEd and related topics. This choice allowed us to focus on a smaller set of data and conduct a preliminary assessment, which is in line with the goal of a scoping review.

The data collection process was adapted from the PRISMA process (Moher et al., 2009), which is usually used for systematic literature reviews (Borrego et al., 2014). The PRISMA process is comprised of four steps: 1) identification of literature through systematic searches of databases, 2) screening of abstracts to discard papers that do not meet selection criteria, 3) appraisal of full-text to discard papers that do not meet selection criteria and/or do not meet quality standards, and 4) analysis and synthesis of collected literature.

In our scoping review, we skipped the first step (identification through database searches) and we focused only on IJSLE as mentioned above. Therefore, we went directly to the abstract screening phase. The first author reviewed all the abstracts of the papers in IJSLE archives up to issue 2 of volume 11, which was the last published issue when the search was conducted, and therefore no keyword search was employed. The main selection criterion was that the paper had to present a research study focused on evaluating the learning experience of the students enrolled in a service-learning course. The abstract screening resulted in 46 papers.

Next, the two authors appraised the full-text of the paper to make sure that the papers presented some sort of evaluation study. In contrast with systematic literature reviews that assess the quality of the a study at the full-text appraisal stage to decide whether to keep or discard a journal article, in our case we did not appraised the quality of the papers at this stage because evaluating the quality of the collected papers was part of our research goals, so we wanted to keep even lower quality studies. To appraise the full-text, the two authors selected 10 papers from the 46 and appraised them independently. Then, they met to compare results. Because the results were very similar, the two authors appraised the remaining 36 papers independently. To evaluate, the extent to which the two authors agreed on the appraisal of the 36 papers, Inter-Rate Reliability was calculated using Cohen’s kappa. The resulting kappa was 0.94, suggesting almost perfect agreement. In fact, the two authors disagreed on one paper of the 36. The two authors decided to keep the paper. At the end of the full-text appraisal, we were left with 21 papers to analyze.

Data analysis

To analyze the 21 papers we used a content analysis (Hsieh & Shannon, 2005) approach. First, the two authors analyzed half of the papers independently, with a focus on information related to the three research questions: 1) focus of the evaluation, 2) procedures of the evaluation, and 3) quality of the evaluation process. Once the two authors completed the analysis, they met to compare and discuss their coding. They came to agreement on the final codebook and coded the remaining papers independently. Finally, they met again to compare the second round of coding and finalizing the findings.

Results

The goal of our scoping review was to gather preliminary information on the focus, methods, and quality of evaluation of the evaluation presented in the papers. Therefore, we organized the results section around these three topics.

Focus

The specific focus of the evaluation studies presented in the 21 papers ranges significantly, but we grouped them in two broader categories: learning outcomes and satisfaction. As reported in table 1, the majority of the papers (n = 15) focused on learning outcomes, while seven papers evaluated stakeholders’ satisfaction. Two studies (Davis et al., 2014; Leigh & Clevenger, 2013) evaluated both learning outcomes and satisfaction. In general, all papers reported that students gained proficiency in the outcomes measured as a result of participating in the respective HumEng or related initiative, which included short intensive courses, one semester courses, and multi-semester courses.

Among the learning outcomes that were evaluated the most common were social responsibility, teamwork, and communication. Other common competencies included global/cross-cultural skills, design, problem solving, and life-long learning. The fact that these specific skills were most commonly studied is not surprising as HumEng initiative have an intrinsic focus on professional skills, community engagement, and design across countries and cultures.

Table 1. Number for papers for each focus of evaluation	
Focus	**N of sources**
Learning Outcomes	15
Social responsibility	7
Teamwork	7
Communication	7
Global/Cross-cultural	5
Applying STEM knowledge	4
Design	4
Problem solving	4
Life-long learning	4
Equity and diversity	3
Leadership	2
Project management	2
Creativity	2
Others cited only once (e.g., reflection, self-efficacy, cognitive processes, and others)	10
Satisfaction	7
Students	6
Community partners	3
Faculty	1

However, although the papers used similar names for each competency evaluated, there was not much agreement among the specific definitions of each competency. For instance, the learning outcome focused on social responsibility comprised a range of different, but closely related perspective. Carberry et al (2013) frame it as an individual ability of identify potential ethical issues and dilemmas of a project. Others instead focused on community engagement. Bratton (2014) evaluated students' ability to understand technology impact and Songer & Breitkreuz (2014) focused on global citizenry. Many of the professional competencies overlapped among each other and it was to some extent difficult to put them in one single box. For example, in assessing project management, Davis et al. (2014) included also "working well with a team on an engineering project", which other papers would have categorized as teamwork. Therefore, while authors of the 21 papers used similar language for the learning outcomes, there was often some discrepancy in terms of the actual meanings. Nonetheless, the coding in table 1 reflects the authors of the collected papers wording rather than our perceptions (e.g., if they used the word "teamwork" we coded it as teamwork even if the definition overlapped with other competencies).

Among the papers that evaluated stakeholders' satisfaction, students' perspective was the one that was mostly appraised. Similarly to the case of the learning outcomes, each paper looked at different, but closely related aspects. To cite a few examples, Bargar et al (2016) asked students to reflect on their experience as compared to traditional coursework, Bichel & Sundstrom (2011) asked to rate the "quality of the course content", and Liguori et al (2014) elicited perspective on the academic structure and the teamwork experience. The community partners were typically surveyed about their satisfaction of working with the students. Only Ermilio et al (2014) included faculty members. However, while students, community partners, and faculty members are key stakeholders, HumEngEd involves even a wider range of stakehoders (e.g., governments, other local organizations, the direct beneficiaries, professional staff of universities, accreditation bodies, professional societies, etc.), which could be included in future research.

Methods

In terms of methods of evaluation, we grouped the methods used in the traditional three categories: quantitative, qualitative, and mixed methods. Quantitative methods were the most commonly used (n = 12), followed by qualitative (n = 5), and finally mixed-methods (n = 4).

Among the quantitative studies, surveys using Likert scales were the most common. For instance, Bielefeldt and Canney (2014) used the Engineering Professional Social Responsibility Assessment survey, which is comprised of 50 items on a 7-point Likert scale. Similarly, Bratton (2014) used the Engineering Self-Efficacy Scale (ESES) which is comprised of 13 items on a 7 point scale. Only one study did not use Likert scale. Budney and Gradoville (2011) asked students to rank a set of 20 competencies from the most important to the least important.

Although many studies focused on evaluating similar outcomes, none of the quantitative study used the same instruments. The only papers that used similar surveys were Perrakos et al (2014) and Carberry et al (2013). In fact, Carberry et al. (2013) used an adaptation of National Engineering Students' Learning Outcomes Survey (NESLOS), whereas Perrakos et al (2014) used the original. The lack of consistency among methods used for measuring the same constructs in these quantitative studies is somewhat surprising as one of the strengths of quantities methods is they enable comparison through standardization.

Among the qualitative studies, reflections were the methods mostly used. Duff et al (2014) and Leigh and Clevenger (2013) collected reflections from students only at the end of the learning experience, whereas Jeffers et al (2015) asked students to reflect before, during, and after their experience. Liguori et al. (2014) was the only study that used interviews as the main method to collect information for their evaluation. The most unique approach was probably used by Lemons et al. (2011), who utilized verbal protocol analysis.

Finally, only four papers used a mixed-method approach. Dukahn and Schumack (2010) combined reflections and multiple-choice questions. Smith et al (2016) grounded their study in Threshold Concept Theory and used both surveys and interviews. Ermilio et al (2014) ran a SWOT analysis with multiple stakeholders and interpreted findings from Likert scale surveys. Perrarkos et al. (2013) integrated surveys with open-ended questions.

In sum, a range of methods has been used, with a clear preference for surveys. Only two non-mainstream approaches were utilized (Verbal Protocol Analysis and SWOT). The most surprising finding was probably the lack of consistency of the methods used among the papers, which prevents any meaningful comparison to be made.

Quality

The last part of our analysis of the papers focused on assessing the quality of the research strategies presented in the studies that we collected. We ranked the studies as high when they presented a complete description of the procedures used and a sound justification of their design choices, as medium when some aspects were missing, and as low when no information on the research design was provided. Overall, we rated only 5 articles as high quality and three as medium. The large majority (n = 13) did not present enough information on their study design and therefore we had to rate them as low quality.

Among the five articles that we rated as of high quality, two (Bielefeldt & Canney, 2014; Carberry et al., 2013) were quantitative methods, two were qualitative (Jeffers et al., 2015; Lemons et al., 2011), and one was mixed-method (Pierrarkos et al., 2013). The three studies that used a quantitative approach (Bielefeldt & Canney, 2014; Carberry et al., 2013; Perrarkos et al., 2013) presented very clear description of the theoretical framework underpinning the instruments they used and the validation process that was followed to make sure that the surveys were actually validated and reliable. Similarly, also the qualitative studies presented a theoretical framework and provided details on the procedures for data collection and analysis as well as ways to ensure the trustworthiness of their studies.

Discussion and future research

In this study, we provided a preliminary overview of the focus, methods, and quality of evaluation studies that focused on HumEngEd and similar initiatives. Although our study is limited to ISJLE, four interesting insights emerged from our analysis. First, we found that there is a lack of consistency in the learning outcomes that were evaluated across the papers, thereby making it difficult to perform meaningful comparison across initiatives. Second, the evaluations have been mostly focused on students, thereby missing a broader range of perspectives from different stakeholders. Third, evaluations have mostly used a limited number of traditional methods, which may be positive for standardization, but it also may limit the types of information that can be gathered, especially when collecting information from projects that have a practical application focus. Fourth, while all the studies showed positive results, the lack of details of the research procedures for evaluation makes it difficult to draw solid conclusions on the benefits of HumEngEd initiatives for students and other stakeholders.

In light of these insights, we recommend that three related areas of research should be undertaken. The first line of research should focus on creating a consistent framework of competencies or learning outcomes that could be applied across the current and future HumEngEd programs across Australasia. A possible approach to this problem could be to undertake a Delphi study and involve multiple stakeholders, including university, industry, local communities, and non-for-profit organizations. For instance, Deardorff (2006) used the Delphi technique to construct a comprehensive framework for defining and assessing intercultural competence.

Second, more research is needed to understand perspectives, motivations, and impact of multiple stakeholders, especially community members and partner organizations and the effect of geographical locations on stakeholders' perspectives. Some efforts to investigate this aspect in local service-learning programs has already been undertaken. For instance, Thompson and Jesiek (2017) developed the Transactional, Cooperative, and Communal framework to describe the nature of partnerships in engineering engagement programs. Such a framework could be used both to evaluate existing partnerships, but also to guide the creation of new partnerships between engineering programs and community partners.

The third line of research is focused on methods of evaluation. This line is directly connected and dependent on the two aforementioned research areas. As a new framework of competencies or learning outcomes is created, the attention could swift on how to actually assess students' learning as an outcome of these initiatives. It would also be interesting to go beyond traditional surveys and interview approaches, and use existing or develop new methods. For instance, a large body of evaluation research has used scenario-based instruments to evaluate a variety of engineering competencies, including, for instance, design thinking (Atman et al., 2014; McKenna, 2007), sociotechnical thinking (Mazzurco et al., 2014), and moral reasoning (Borenstein et al., 2010). Furthermore, evaluation procedures such as program logic and similar should be considered.

Finally, a larger, more rigorous systematic literature review should be undertaken in order to confirm or reject the four aforementioned insights and inform further research.

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Students' Perception of Intensive Engineering Subject Delivery by an Australian Academic at an Indian University

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CONTEXT: Intensive teaching formats, also known by various synonyms- accelerated, block, time-shortened, compressed, condensed, have been widely used to teach undergraduate engineering subjects both at domestic and, most commonly, at international partner institutions. The durations of these intensive teaching forms also vary- over one or more weeks, over one or more weekends, over several evenings and/or a combination of them. The extent to which the subject delivery is 'intensified' also varies from discipline to discipline, subject to subject, and institution to institution. Even though intensive teaching formats are becoming common place in engineering education, it is still unclear how they impact on student learning, particularly in engineering subjects that require huge amount of mathematical problem solving skills, which usually take a longer period of time and rigorous practice to be developed. This study investigates an important aspect of student learning- how local engineering students perceive the intensive teaching of engineering subjects by international academics. Case study is conducted at an Indian partner institution where a week-long intensive teaching was adopted to teach an undergraduate civil engineering subject by an Australian academic staff.

PURPOSE: This study aims to explore some important research questions- what do local engineering students think of intensive teaching by international academics? Are there any particular issues we need to worry about? Answers to these questions are based on a case study at an Indian institution taught by an Australian academic.

APPROACH: In order to understand what offshore engineering students think of intensive teaching of engineering subjects, this study adopted questionnaire approach to collect original data from students at an Indian institution by asking them about their perceptions through a series of statements. Five-point Likert-scale questionnaire was developed and responses were collected. Both quantitative and qualitative responses were analysed in order to elicit engineering students' perceptions of intensive teaching.

RESULTS: The analysis of the responses showed that the students perceived intensive teaching mode quite favourable as compared with similar experiences in Australia. It might be due to local socio-cultural context such as consequences of bias, social desirability and social acquiescence. Nonetheless, three issues, which were somewhat similar to other experiences elsewhere, were identified. First, students felt that they did not have sufficient time (1 week delivery was too short) to practise and develop problem solving skills in an engineering subject. Second, students found it difficult to concentrate and engage in learning sessions for long hours. Third, it was important to modify learning resources to include local context (standards, data and issues) when taught by an international academic staff.

CONCLUSIONS: This finding highlights the importance of addressing common issues in order to further improve the 'intensive' off-shore delivery of engineering subjects, particularly extending intensive duration, having sufficient breaks in between learning hours, learning resources to include local context (local standards, data, problems, field visits) when taught by off-shore academics and ensuring assessment tasks are appropriate for intensive format.

KEYWORDS: Intensive teaching, engineering subject, offshore, students' perceptions

Introduction

Most engineering schools in Australia schedule their courses/programs in ‘traditional’ subject/unit delivery formats several times per week, typically for 11 to 14 weeks (trimester or semester or other ‘normal’ duration). In recent decades, however, there has been an increase in other than ‘normal’ subject delivery format including intensive course delivery with no significant loss in contents or student contact times (Vreven & McFadden, 2007) due to a number of reasons- changing student demographics and demands; financial constraints and decrease in government funding and globalisation and international standing (Davies, 2006; Scott & Conrad, 1992), to name a few. Intensive learning specifically and adult education in higher education generally has made enormous inroads into higher education because they are money-makers (Wlodkowski & Kasworm, 2003). Non-traditional (part-time, working, matured, demanding, heterogeneous) student cohorts, financial pressure for academic institutions to maintain enrolments by offering alternatives to these non-traditional students by accommodating their schedules, and the necessity of building international educational collaborations and partnerships have resulted in changes in teaching methods as traditional teaching methods are no longer convenient for today’s students (Davies, 2006) and they are also resource extensive.

Intensive delivery usually means that, rather than distributing face-to-face or online teaching and learning times in small, even, time-slots throughout the semester or trimester or other ‘normal’ duration, the equivalent learning times are allocated to very seldom, but for much longer blocks of times. Several synonymous forms and terminologies of intensive teaching formats- accelerated, block, time-shortened, compressed, condensed, immersed, concentrated- have been widely used to teach undergraduate engineering subjects both at domestic and, more commonly, at international partner institutions by Australian academics. Domestically, summer sessions and interim sessions are commonly in practice to fit the time slots between trimesters or semesters. Internationally, intensive teaching to local students at their institutions by an international academic staff is further intensified into just over a week or over few weeks. The durations of these intensive teaching formats also vary- over one or few weeks, over one or more weekends, over several evenings and/or a combination of them. The extent to which the subject delivery is ‘intensified’ also varies from discipline to discipline, subject to subject, and institution to institution.

Offering courses or units in intensive mode is not new and continue to be a part of the changing higher education landscape at Australian universities. Existing studies, albeit very limited and conflicting, have identified some advantages and disadvantages of intensive teaching formats for students, for teaching staff, for academic institutions and for educational outcomes. They have also suggested some best practice guidelines.

Advantages for students include, among others, flexibility and work/study-life balance; improved time management skills; increased motivation, commitment, concentration, engagement and interaction, rewarding and stimulating; focused, efficient, challenging and enjoyable; and closer relationships among students (Burton & Nesbit, 2002; Daniel, 2000; Grant, 2001; Scott & Conrad, 1992). Advantages for teaching staff include, among others, students tend to prepare better for intensive sessions; better student attendance; integration, concentration and continuity; flexibility and work-life balance; closer relationships with students; satisfaction, motivation and enjoyment; and similar, if not better, in terms of contents and learning outcomes (Burton & Nesbit, 2008; Grant, 2001; Scott & Conrad, 1992). Advantages for academic institutions include increased enrolments, reduced resources and allows for staffing flexibility and guest speakers (Burton & Nesbit, 2002; Grant, 2001). Advantages for educational outcomes include, similar or better student performance compared with ‘traditional’ format; does not compromise short- and long-term knowledge retention; increased quality of student learning and experience in terms of interaction, commitment and academic performance; and context-sensitive learning that can have enormously high focus and impact on student learning (Burton & Nesbit, 2002; Faught, Law, & Zahradnik, 2016; Grant, 2001; Scott & Conrad, 1992).

On the other hand, intensive subject delivery has often been criticised as being too intensified ‘to produce anything of educational value’, reproached for sacrificing breadth, short-shrifting academic standards to accommodate time constraints, and obliging students to cram information at the expense of genuine learning and development (Scott & Conrad, 1992; Slichter, 1927). Many educators, in general, are concerned about learning outcomes (Daniel, 2000). In addition to these perceived disadvantages for educational outcomes, past studies have identified a list of disadvantages of intensive format for students and for teaching staff. Disadvantages for students, among others, include difficulties in switching to new materials without having time to review or reread old materials; difficulties in completing assessments to a high standard due to limited preparation times; less opportunities to meet teaching staff outside classes; excessive workload and information overload in a short period of time; and unsuitable, stressful, overstimulation and difficult for some students, particularly the slow learners (Henebry, 1997; Scott & Conrad, 1992). Disadvantages for teaching staff, among others, include necessity to revise, redevelop and redesign learning outcomes, contents, assessments, resources and activities; limited or decreased opportunity for extensive coverage; increased workload and time pressure- too little preparation time and too rapid assimilation; fatigue or difficulties in maintaining energy; little opportunity to adjust learning materials; difficulties in responding to student feedback on time; and unsuitable for some quantitative and difficult subjects (Burton & Nesbit, 2002; Daniel, 2000; Grant, 2001; Scott & Conrad, 1992).

A considerable amount of the literature on intensive teaching format appears to exist in academic areas where skill acquisition is paramount, rather than discursive, conceptual learning and it may be critical in assessing the value of intensive teaching in various subjects (Davies, 2006). While there is recent significant growth of accelerated degree programs, there is little empirical research regarding the quality and impact of accelerated degrees on adult learning (Kasworm, 2001). The literature in this area is not extensive. Even though intensive teaching formats are becoming common place in engineering education, it is still unclear how they impact on student learning, particularly in engineering subjects that require mathematical problem solving skills, the development of which usually takes a longer period of time and rigorous practice. Several research questions can be asked:

- Do ‘intensive teaching’ format, intensity, duration, times of the day or week or season make a difference in engineering students’ academic performance and achievement?
- Do engineering educators revise, redevelop and redesign learning outcomes, contents, assessments, resources and activities for ‘intensive teaching’ contexts?
- How and why do engineering educators, institutions and students choose a particular format of ‘intensive teaching’?
- What are the factors that impact the quality of ‘intensive teaching’?
- How do engineering students perceive and learn in ‘intensive teaching’ format?
- Do engineering students learn, achieve, reflect and retain knowledge more effectively and efficiently in ‘intensive teaching’ format?

Unfortunately, existing literature does not fully answer these questions, neither does this study as it is difficult to accommodate all these issues in a single study. However, this study attempts to investigate an important aspect of student learning- how engineering students perceive the ‘intensive teaching’ of engineering subjects in a particular context. A case study is conducted at an Indian partner institution where a week-long intensive teaching was adopted to teach an undergraduate civil engineering subject ‘Road Design & Safety’ to local students at their institutions by an Australian academic. The learning outcomes and associated contents of the subject, in brief, included (i) discussion of the linkages between road design and safety, (ii) identification, collection and calculation of road design input parameters, and (iii) design and detailing of road geometric elements based on Australian experience and design standards. The teaching method adopted was mostly lecture-tutorial based sessions and in-class discussions. At the end of the week, an examination that contained questions of several levels of difficulties was conducted to assess the students' learning achievement.

Study method

As previously discussed, the primary objective of this study is to capture engineering students' perceptions of intensive teaching of engineering subjects in a particular context. Questionnaire was used for eliciting such perceptions. The student learning experience questionnaire was designed using well established literature in Study Process Questionaries (SPQ) (for example, (Biggs, 2011; Biggs, Kember, & Leung, 2001)) that included a range of statements that help capture these perceptions through students' responses. Qualitative data were also collected in addition to quantitative responses.

In total, 59 questionnaires were completed physically in the classroom by the students collected by a non-teaching staff in 2016 representing a response rate of 98.33%. The questionnaire requested respondents to provide their perceptions and opinions about statements related to subject, teaching staff and their own learning as either (1) strongly disagree (2) disagree (3) neutral (4) agree or (5) strongly agree. These statements were derived from several studies (Biggs, 1987, 2011; Biggs et al., 2001; Jenkins, Edwards, Nepal, & Bolton, 2011; Justicia, Pichardo, Cano, Berbén, & De la Fuente, 2008; Kember & Leung, 1998). Unidentifiable background information about the respondents was also collected. These 5-point Likert-type ordered responses were statistically analysed in order to gain insight into the research questions.

Respondents' Profile

The responses collected were from third year Bachelor of civil engineering students at an Indian university. The student cohort were all male students, who were freshly graduated from high school and of 18-21 years of age (only one student was 22 year or older). This profile is something different than the Australian engineering student cohorts. As expected, about 65% of them had Hindi as their first language, about 15% of them indicated English as their first language and remaining 20% spoke Punjabi or other languages. About 70% of them had achieved 50-70% overall percentage marks before this intensive subject.

Data analysis and results

Even though several existing studies have used mean and standard deviation to describe ordinal scale data, the most appropriate way of analysing them is through median, mode, range and percentiles as discussed in the following sub-sections.

Quantitative analysis of the students' perceptions of the intensive Subject

The resulting descriptive statistics (median, mode, range and percent difference) of the responses relating to students' perceptions of the intensive subject are summarised in Table 1. Both median and mode scores vary from 4 to 5 and the ranges are 1-2. The small ranges indicate that students' responses are consistent. It is interesting to see that scores of the statements relating to assessment (exam) are slightly lower than other statements. It may indicate that the assessments (exams) were not properly designed to suit intensive learning environment or students got very limited time to prepare for assessments (exams).

Table 1: Descriptive statistics of students' perceptions on the subject

Study Process Questionnaire (SPQ) Statements	Median	Mode	Range		Percent Difference (Strongly Agree/Agree MINUS Disagree/Strongly Disagree)
			Max.	Min.	
1. The Subject was designed appropriately to cover safety and road design details	5	5	5	3	96.6%
2. The Subject was structured well at the level suitable for students	4	4	5	2	87.9%
3. All contents offered in this Subject were of significant importance for working as a professional road designer	5	5	5	3	91.3%
4. The Subject Learning Outcomes (SLOs) in this Subject were clearly identified	4	4	5	3	92.9%
5. The quality of teaching in this Subject helped me to achieve the Subject Learning Outcomes (SLOs)	5	5	5	3	93.0%
6. Assessment (exam) of the Subject was appropriate and fair	4	4	5	2	73.7%
7. Overall, I am satisfied with this Subject	4	4	5	3	93.1%

Quantitative analysis of the students' perceptions of teaching staff

The descriptive statistics (median, mode, range and percent difference) of the responses relating to students' perceptions of teaching staff are summarised in Table 2. Both median and mode scores vary from 4 to 5 and the ranges are 1-2. The small ranges indicate that students' responses are consistent. All scores were similar. There are no significant outliers.

Table 2: Descriptive statistics of students' perceptions of teaching staff

Study Process Questionnaire (SPQ) Statements	Median	Mode	Range		Percent Difference (Strongly Agree/Agree MINUS Disagree/Strongly Disagree)
			Max.	Min.	
8. Teaching staff had expert content knowledge of the Subject	5	5	5	4	100.0%
9. Teaching staff had appropriate teaching skills	5	4	5	3	98.3%
10. Teaching staff was able to relate the contents with applications	5	5	5	3	94.8%
11. Teaching staff had strong beliefs, values, motives, attitudes and expectations in teaching and learning	5	4	5	3	96.5%
12. Overall, I am satisfied with the teaching staff	5	5	5	3	96.5%
13. Overall, rate your satisfaction with this Subject	4	4	5	1	96.6%

Qualitative analysis of the responses

In addition to the quantitative responses, qualitative responses were also collected. Respondents were asked to provide experiences in relation to (i) the best aspects of the subject, and (ii) aspects of the subject in need of improvement. These qualitative responses were closely scrutinised. Some examples of the responses are provided below:

Some examples of good aspects:

"Learnt about road safety and design."

"… increased our knowledge of road safety and design."

"The importance of the topic in India. We should train ourselves for this."

"Strong practical approach and excellent teaching."

"… provides us with exposure of types of teaching in other countries."

Aspects in need of improvement:

"Standards were needed Indian"

"Indian system of roadways was not explained in detail."

"… if students get practical knowledge, i.e., by taking them to road construction site…"

"There should be a site visit of the roads which we are studying to design".

"Duration of the course should be more."

"I think doing 7 hours of the subject in a day was a little boring".

"Needed more time"

"Numerical type of problems needed more time to practice."

"This subject is too short. It should last for at least 2-3 weeks, so that we can learn…"

"Too much contents for a week to learn and do a test"

A few important observations can be made from these qualitative responses. First, majority of these responses are related to learning 'contents' rather than learning 'process' and 'outcomes'. This observation is expected in an Indian learning context as content-focused learning at Indian academic institutions are widely known. Second, even though students appreciated the quality of subject and teaching staff, they felt that the intensive delivery of the subject was not adequate for them particularly due to long hours of delivery, limited time to practise numerical problems, lack of field visits for practical knowledge and learning resources not being modified to include local contexts. Most of these issues are associated with the limited time availability for the subject. Hence, one week of intensive delivery may not be sufficient for engineering design subjects.

Conclusion

This study adopted a questionnaire approach to collect original data through a range of statements that help explore the students' perceptions of intensive delivery of an engineering subject. The computed quantitative statistics show that the students evaluated quite favourably the subject and the teaching staff as compared with similar Australian context. The analysis of qualitative data reveals four important issues to be addressed. First, students felt that they did not have sufficient time (1 week delivery was too short!) to practise and develop problem solving skills in an engineering subject. Second, students found it difficult to concentrate and engage in classroom environments for long hours. Third, it was important to modify learning resources by including local contexts (local standards, data and problems) when taught by international academics. Fourth, students indicated that the assessment was somewhat not appropriate. Future studies can be extended to students' academic performance and achievement, factors that impact the quality of learning and learning process in intensive delivery and other research questions listed on Page 3 of this paper.

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Engineering as a "Thinkable" Career for Women

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SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

Women often view engineering as a career choice outside their frame of reference or personal experience. Engineering offers excellent career pathways and financial security but participation rates of women in engineering remain low, particularly in traditional programmes such as civil, mechanical and electrical engineering. Although women's participation rates in New Zealand engineering programmes are increasing slowly, they are still less than 20% across all programmes compared to 60% women in all tertiary programmes in 2016. This study reports on the findings of interviews conducted with several recipients of a national scholarship for women enrolling in Year 1 engineering. The study investigated their specific reasons for deciding to pursue an engineering career.

PURPOSE

To determine the reasons recipients of a national scholarship for women enrolling in engineering had chosen engineering as a career, and factors that contribute to their retention.

APPROACH

Seven recipients from two universities who had received a national scholarship for women entering a professional engineering programme, two engineering academics (one woman, one man) and one tertiary STEM coordinator (woman) were interviewed. Participants were given potential questions prior to the Interviews, which were conducted face-to-face (academics) or by phone or Skype (students) and lasted 30 to 80 minutes. With permission, interviews were recorded and transcribed then anonymised for analysis.

RESULTS

All recipients were academically capable, had taken STEM subjects at school, and self-identified as confident about their abilities and/or enjoyed STEM subjects. Parental involvement in the tertiary environment and engineering education, transition preparation between school and university, and university and work, and appropriate technical support staff were important support factors.

CONCLUSIONS

Creating learning environments that emphasise care and respect for the students, as well as overseeing student interaction during group work to ensure equitable contributions to practical as well oral and written aspects can make a differen
ce to students' satisfaction within an engineering programme, and interest in engineering as a career. Ensuring gender is considered when developing strategies, examples and projects is important, as are the attitudes of technical support staff.

KEYWORDS

Engineering, gender, learning environments

Introduction

Many women consider participating in engineering as unthinkable, often because it is outside their frame of reference or personal experience. Although engineering offers women excellent career pathways and financial security, the proportion of women in engineering is less than in other careers (Little & León de la Barra, 2009). Nearly 60% of New Zealand tertiary enrolments in 2016 were women (MoE, 2017). They made up less than 20% of the engineering cohort in 2012 (MFA & IPENZ, 2012), although numbers are increasing (E2E, 2017). Women who decide to study engineering need to overcome societal perceptions that engineering is a "boys' club" and often involves "dirty work". They often face unintentional gender bias in everyday interactions from, for example, parental guidance, media imagery, workplace culture, and teaching practices and resources (Corbett & Hill, 2015). Researchers and the engineering community (IPENZ, 2015) have examined how to promote women's interest in engineering, but the gender gap remains stubbornly persistent. International literature on science, technology, engineering and math (STEM), particularly engineering educational aspects is beginning to explore how cultural and social factors, particularly in engineering education, and unconscious bias messaging impacts on women (Zecharia, Cosgrove, Thomas & Jones, 2012).

To identify reasons for the gender gap and what encourages women to consider engineering as a thinkable career choice, we explored the perceptions and experiences of seven women recipients of a national engineering scholarship. The investigation examined how their aspirations and experiences influenced their decisions to pursue an engineering career. It also examined the viewpoints of three tertiary academics with responsibilities for engineering education programmes. Examining the perspectives of academically capable women engineering students and academics will assist with developing strategies and interventions that may help reduce the gender gap and make engineering a thinkable prospect.

Methodology

The investigation aimed to:

- explore reasons and characteristics of women who decide to major in engineering in two New Zealand universities,
- identify the support they are currently receiving or would like to receive, and
- identify programmes that encourage women to consider an engineering as a career

We adopted an interpretative approach (Cohen, Manion & Morrison, 2011), which allowed a focus on participant's views and experiences. The study had ethical consent from the Ethics Committee, Te Kura Toi Tangata Faculty of Education, The University of Waikato. All participants gave informed consent for their involvement.

Names of recipients of a national scholarship for women entering first year full-time study in undergraduate professional engineering were obtained from a public database. Eleven recipients at two universities were contacted and seven agreed to be interviewed. They were between 17–25 years and ranged from pre-entry to post-graduate students in a range of engineering programmes (chemical, electrical and mechanical). Although a small sample, it provided a broad base for capturing a range of perspectives from which to triangulate characteristics and themes. The academics were senior leaders in their engineering school.

Before a semi-structured interview, participants received a list of potential questions focused on factors that influenced their decision to pursue engineering, the nature of their experiences, and the extent to which supports or recruitment/retention strategies helped overcome barriers to entry and completing their degree. Interviews were done via phone or Skype and lasted 30 to 80 minutes. Academics had a different set of questions and were interviewed face-to-face for 30 to 70 minutes. With permission, interviews were recorded, transcribed, and anonymised. The transcripts were subject to thematic analysis to identify themes associated with experiences that were meaningful to the participants, and how these experiences shaped their decisions to seek and then stay in their engineering majors/career.

What Made Engineering Thinkable?

Scholarship recipients had committed to an engineering programme and were academically able. All had taken STEM based subjects and identified as confident about their abilities and/or enjoying these subjects “I’ve always really enjoyed chemistry, calculus, and physics ... I thought if I enjoyed these, I’m sure to enjoy engineering” (SE1, 2017). All respondents chose engineering due to the academic strength in science and mathematics and repeatedly expressed how engineering allows them to use their problem-solving skills and challenges them to apply theoretical learning: “[I] like logic and being practical” (SE3, 2017) and “[A]ll the different things you get to learn and the problems you get to solve” (SE1, 2017).

Participants demonstrated pride and accomplishment in doing and completing an engineering degree, were highly motivated to succeed, had persistence (Lehr, Finger, & Snelling, 2014) and high levels of self-efficacy and confidence in taking a difficult subject. They considered their career aspirations matched their personal life expectations (Grays, 2013). “I’ve always studied hard and stuff like that. But, I guess I have confidence in myself because if I have confidence in myself I think I can pretty much do anything” (SE1, 2017).

Most participants had self-selected an engineering career by Year 12 “I always really, really, wanted to be an engineer. So, I was looking up all the different engineering things myself” (SE1, 2017). All students had independently researched to compensate for what they considered the limited advice available from their school. “[T]here wasn’t a lot of knowledge [or] understanding around what it was. I know the careers advisor thought it was a great idea but it certainly wasn’t advertised in school” (SE4, 2017).

All participants were attracted to engineering not just for the technical applications but the creativity, innovation and collaboration involved and the possibility of making things work or be better. “You are working in a team that you are doing something that is innovative that hasn’t been done before” (SE4, 2017). Most wanted to improve or help society. “I also liked how the field of engineering meant in some way you could give back to the community” (SE6, 2017). The academics reiterated this aspect: “I think that the only way we are going to lift the situation of a depleting planet is to get women into engineering” (A2, 2017). Being good guardians and developing sustainable practices indicates an opportunity to embed socio-scientific issues and civic engagement opportunities into the curriculum (Garibay, 2015).

The students considered they were working towards/having a career with status, financial stability, and diverse pathways within and beyond engineering - “I felt engineering was or is a respected (sic) and again I felt this would keep doors open” (SE6, 2017) and “I liked [engineering] because it’s transferable, it’s something that is well recognized, and you can go to lots of different places” (SE5, 2017). Two participants thought engineering would allow a better work-family balance, often considered important for women (Corbett & Hill, 2015).

Students and academics both referenced the influence of family when deciding on degree choice. All students had some form of engineering connection, e.g. parent, siblings, family friend or acquaintance. “[My brother] studied electronic engineering … and also my cousin who is two years older than me, he is studying the same degree I will be studying … so like I’ve had a lot of support from them” (SE3, 2017). All studens considered their parents were supportive of their aspiration to be an engineer, “[My parents] took a lot of personal time out to help me with that - that was obviously encouraging” (SE6, 2017).

As noted by Lehr *et al*. (2014), many participants said their fathers played a large role in supporting their degree selection - “When I was trying to decide what kind of engineering I wanted to do [Dad] used his contacts in the business world” (SE6, 2017). As reported elsewhere (Dawes, Long, Whiteford & Richardson, 2015), teachers were cited as being influential: “I remember my physics teacher has been amazing and then my chemistry a (sic) incredible capable" (SE1, 2017). Students hoped their future tertiary academics would be just as welcoming and competent - "I'm just hoping that I have good lecturers because I've only had a few teachers who were really annoying and get on my nerves" (SE3, 2017).

Barriers that Make Engineering Unthinkable

Understanding the nature of the engineering profession is recognised as a significant barrier to the early formation of career intentions (Godfrey & Holland, 2011). Gender stereotypes, including archetypal descriptors of engineering as a male domain, can exacerbate this situation (Cheryan, Master, & Meltzoff, 2015). The participants reflected on their limited knowledge about engineering and lack of familiarity with the roles of engineers, which were often filled with ill-defined stereotypes, misconceptions and negative imagery - "For me, I have still got that perception of computing, software and electrical being male dominated even though I'm in engineering myself, you know. That's probably a stereotypical view of it" (SE6, 2017*)*. Lack of information and large selection of choices within engineering degrees also created feelings of being overwhelmed with choice, along with a level of self-doubt: "I was like yup that sounds like me - like luckily I think I picked the right one, but in terms of knowing which one to pick it's kind of a hit or miss really; yeah, a lot of it I had to research myself. I didn't really know" (SE3, 2017).

Gender stereotypes may deter women from entering engineering disciplines (Corbett & Hill, 2015), and this can occur at an early age (Broadley, 2015). Most participants commented on this - " …[be]cause girls' toys are quite dressy and hair and stuff […] boys' toys are more building and stuff like that so at a young age … that might shape their decision" (SE1, 2017); "I think when we are brought up as kids we are sort of socialised differently. It's sort of all these stereotypes like boys fixing things and that and girls are like taking care of other people" (SE7, 2017). This participant commented that feelings of not having the necessary pre-engineering skills created restrictions, but noted this was not only an issue for girls - "I didn't, you know fiddle around with electronics in my spare time - I really started off on the back foot. And yeah, guys are like this as well—as not all guys who do engineering do that. So, it's just not a problem with females, but I personally felt that that was my disadvantage and I never really caught up with that" (SE7, 2017).

Consistent with other research (e.g., Sakar, Tytler, & Palmer, 2014) our participants identified poor quality careers advice as a barrier in their decision-making. "Engineering wasn't pushed at my school. I was the only one … some of my teachers were surprised I wanted to go into a male dominated career "(SE5, 2017). The academics considered schools might not encourage or support girls to enter engineering "[W]e don't get a flow of [female] students from [co-ed school] … and it's like [girls] are pressured- role modelled into the particular careers before we get to see them- we can't attract their interest at all" (A1, 2017).

While all the participants had supportive parents, they were very aware that limited parental support and understanding could be an impediment for other girls - "I think that their parents probably don't know what engineering is about and they think their son or daughter being a doctor would be much better for them" (SE1, 2017). This view was shared by the academics interviewed - "I think they are being steered away from engineering both by their mother and their father. The parents don't understand what engineering is and they (girl children) get these messages pretty early" (A2, 2017). This preconception aligns with the literature and indicates that differential expectations and treatment of sons and daughters can influence girls' decisions about career options (Sakar *et al*., 2014).

Strategies to Make Engineering Thinkable

There is much debate on why women do not participate in engineering education and engineering (Fox, Sonnert & Nikiforova, 2009) with no obvious "one-size fits all" model for effective recruitment and retention (Little & León de la Barra, 2009). Research shows that treating different groups in the same way does not produce the same outcomes (Ohland *et* *al*., 2011), suggesting organisations need to use tailored, coordinated and multi-pronged approaches. There is evidence that long-term success relies on institutional and structural frameworks rather than student-centric approaches that construct students as the problem (Fox *et al*., 2009, 2011). The suggestions our participants offered for enhancing recruitment and retention echo those in the literature including providing early access to models of what engineers do and contribute, community outreach activities, and considering university programmes.

Early school-based strategies

Positive early exposure to STEM experiences increases woman's likelihood of pursuing STEM-related studies (Hirsh, Berliner-Heyman, Cano & Cusack, 2017). Participants agreed that breaking down stereotypes and correcting misconceptions and misrepresentations of engineering needs to occur early so engineering becomes an option for girls and women - "I think getting people to talk to … not only high schoolers but you know young high schoolers - introduce this option Year 7 and 8 and not just the final year of school" (SE5, 2017).

Participants, echoing Broadley (2015), suggested that careers education be introduced at an early stage and that engineering ideas be integrated into the school curriculum - "The main thing would be that it would be encouraging to see schools talk about engineering more" (SE6, 2017) and "Making engineering specific to class work would be good" (SE6, 2017). Research supports our participants' view that access to career advisers who are knowledgeable about the breadth of engineering choices is essential (Sakar *et al*., 2014), and that universities could usefully provide resource material and professional development workshops to careers advisors to increase their understanding of engineering activities.

Tertiary institution based strategies

Leaper and colleagues (2012) suggest the first step is for institutions to acknowledge gender inequalities and then address the changes required openly. The students in our study supported this approach as an imperative: "I think the tertiary sector needs to see it as a priority and make a commitment that they want to help make this change and come up with an action plan and research this well … but isolating girls wouldn't help" (SE4, 2017).

For their part, the academics reported having gender challenges (and falling numbers) and two of the three reported there were no formal targets or institutional strategic plan to tackle the issues, although independent activities were occurring - "We don't have any plans, they are just unofficial things that would be a good idea" (A3, 2017).

The student participants suggested that gender-tailored workshops would help prepare them for difficult encounters and transitions during their studies - "We only have one type of professional paper in our final year at [university] and I mean it really needed to be more than that" (SE5, 2017). "Trying to learn how to be a female in a male dominated career so making sure you're not seen as passive. It's something I need to get to grips with" (SE6, 2017). They emphasised the value of external relationships with groups such as Women in Engineering, Engineering without Borders and internships and advocated having more explicit linkages of this kind - "I think students would really benefit from that type of support around connecting up with internships" (SE5).

Social connectedness can help counteract the 'chilly climate' in engineering and recognise the disposition of female students towards relationships and support (Corbett & Hill, 2015). One participant made a plea for the university/lecturers to reach out and talk with students - "[I]f the university could reach out and say you know, we are happy to have these conversations please, please, come and talk to us - this is my number call me" (SE4, 2017). Grays (2013) suggests that universities need to encourage faculty members to interact with female undergraduates outside the classroom as this helps improve retention and student engagement. This was reinforced by SE4's comment - "Lecturers need to reach out" (SE4, 2017). Godfrey and Holland (2011) noted that engaging women students in faculty discussions, allowing them to be involved in recruitment drives, and giving leadership roles demonstrates visible commitment, which creates a sense of belonging.

The participants showed interest in allowing more choice and diversity across the papers in engineering programmes. Corbett and Hill (2015) claim such measures can increase women recruitment and retention. Academic 3 agreed there was a need for more diverse tasks - "[W]e do boat building in the first year and I keep saying that we should find other examples such as making a solar sewing machine. A very feminine sort of thing but it is still a problem" (A3, 2017). One student mirrored this need for change, although she was less concerned with any 'feminine' focus: "Definitely some of the projects … are pretty old school. We did one project and designed a crankshaft or something and wasn't very interesting and people don't do that stuff in nowadays and it's probably like about 20 years out-of-date" (SE7, 2017). In a wider sense, participants advocated tasks that allowed for creativity - "Girls who are attracted to engineering that are more creative and it's a side you only get to show later on and maybe initially you don't get to see much of that" (SE6, 2017).

Several participants recognised the value of mentoring and access to role models - "I think that [mentoring] would be something that would be quite good" (SE4, 2017); and "Making sure there are role models for them to them to look up to—who have really cool engineering stuff - there are people like this- there is another type of engineer, not just male builders" (SE2, 2017). Two participants indicated being a mentor would increase participation. Academics supported this approach. "I think a mentor can make quite a bit of difference and many sorts of different mentors for different things" (A3, 2017). Their identified need for mentors echoes recent research showing that effective mentoring programmes can help overcome identified barriers and improve retention, encourage an engineering identity, enhance self-efficacy (Broadley, 2015; Poor & Brown, 2013; Wang & Degol, 2013) and help counter negative stereotypes and encourage self-belief.

Tertiary costs make the strategic allocation of funding pivotal for tertiary institutions and students. Several student participants stated that their scholarship was a real motivator for them to pursue engineering - "Having scholarships are helpful especially if you need to move cities" (SE4, 2017); "[I]n terms of money and scholarships and all that, which was a huge thing for me" (SE3, 2017). Targeted scholarships encourage social mobility especially in non-traditional fields such as engineering. Extending scholarship to part-time students or students wanting to retrain could promote engineering (Godfrey & King, 2011).

Community-centred strategies

Tertiary outreach, which plays an influenctial role in bringing people together with a common aim, has grown to become a mainstream activity. Christe and Feldhaus (2013) claim that students who attended outreach projects were more likely to enrol in an engineering programme and were often more academically prepared. Most students in our study had participated in some form of outreach and that "Doing internships" (SE3, 2017); "… show[ing] that they can do Engineers without Borders" (SE5, 2017) and "… [being] well prepared: information, robotics, camps" (SE2, 2017) are positive strategies for recruiting women.

All student participants shared examples of their parents continuing care and support, and suggested that forging better relationships with the parent community would be a beneficial recruitment and retention tool - "Maybe, getting parents involved" (SE5, 2017); "Simply by inviting them along to events, engineering opportunities or talks with their kids when they are younger and having parents there as well" (SE5, 2017). This type of inclusive practice has been successfully integrated at Harvey Mudd College in the US (Corbett and Hill, 2015).

The participants recognised that first impressions are important and emphasised that marketing material needs to illustrate to women that they are welcome. For example, potential students need to understand what and why - "I think engineers need to market themselves a whole lot better just so people can know - I think in my social circles it not so much that now that they are scared of doing engineering because they are a female but it is almost that they seem to not even know what it is" (SE4, 2017). One participant offered an example, which illustrated how influential implicit messages could be. "I do remember the photo on the website is a guy and I remember thinking there should be a girl there too" (SE2, 2017). Bystydzienski and Brown (2012) identified that perceptions and choices are influenced by how engineering is presented on websites, career days, and gender-targeted activities. Godfrey and King (2011) recommend institutions establish clear publication guidelines to attract a more diverse set of students to engineering. One of the students echoed this sentiment: "[W]hen they had the open day they kind of showed people the chemistry labs and things like that which enthuses some students. But, I think showing the more unusual things you can do with it - some of the artistic side, the biomedical side of things - like that would be really important" (SE5, 2017).

Conclusions

"I love engineering so much that I'm sure if more girls knew about it they'd enjoy it too!" (SE6, 2017). This display of zeal and passion for engineering by this scholarship student is what the engineering community hopes to hear.

The students in this study viewed their experiences as an under-represented group in engineering in a positive way, and it was their "thinkable" outlook that underpinned their direction and persistence. This view has practical implications if we are to build on local, national and international research and encourage more girls and women into engineering. Our analysis shows that the tertiary sector has a pivotal role in helping make engineering careers thinkable for young women. This would require changes to be framed and pursued at the institutional level, and include student-centric activities. However, if engineering is to become thinkable for young women, then collaboration amongst schools, universities and communities is critical. Potential initiatives for recruiting women into engineering include outreach programmes, improved careers advice, an inclusive culture in engineering programmes, mentoring, and focussed community engagement. We anticipate that these and other similar initiatives would be of significant value for enabling prospective female students to consider engineering as part of their future.

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The role of a humanitarian focus in increasing gender diversity in engineering education

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SESSION S3: Integrating Humanitarianism in Engineering Education

CONTEXT Diversity within project teams is known to be advantageous when tackling complex problems, such as the barriers to achieving the Sustainable Development Goals (SDGs). To enhance the engineering profession's contribution to the SDGs, it is now more important than ever that a lack of gender diversity in the sector is resolved. Research from around the world is demonstrating that linking STEM subjects to positive social impact leads to a more gender diverse student cohort. As an organisation with both an explicit focus on social impact and relatively high participation of women in its education initiatives, Engineers Without Borders Australia (EWB) is well placed to further investigate the current and future role that humanitarianism plays in the creation of a gender diverse engineering sector.

PURPOSE This research investigates the links between gender diversity and humanitarian engineering education initiatives, and explores initial insights into how factors such as global relevance and social impact could be utilised by engineering educators to create a more diverse engineering profession.

APPROACH Students opting to participate in EWB humanitarian engineering education initiatives were asked via a survey tool to identify their gender and top five motivations for choosing to participate in that program. A predefined list of 24 motivations was generated from an analysis of previous motivation statements. The motivation statements were categorised into six themes: values, career, social-connectedness, social pressure / encouragement, understanding, and enhancement.

RESULTS Preliminary analysis of survey responses indicate that both men and women are primarily motivated to participate in EWB initiatives due to values-alignment, regardless of the program type (e.g. formal curriculum, volunteer opportunity, overseas professional development opportunity). When looking at the broader data set male respondents tend towards 'career' and 'enhancement' motivators with female respondents tending towards 'social connectedness' motivators.

CONCLUSIONS / LESSONS LEARNED This research demonstrates that both men and women are motivated to participate in humanitarian initiatives primarily due feeling aligned with the aim of that initiative. The two initiatives discussed, which are currently attracting a relatively high proportion of women, provide a rich context to begin to understand the implications of humanitarian engineering offerings on diversity as both humanitarian engineering and gender diversity become increasingly prioritised at Australian universities.

KEYWORDS

Gender diversity; Social value; Humanitarian engineering.

Introduction

Engineers have a reputation for solving complex problems; the 2030 global development agenda laid out by the United Nations (2015) in the Sustainable Development Goals (SDG's) certainly contains complex problems. Many, including Sinha (2015), believe that engineers will play a vital role in meeting these challenges with participation critical in the goals of 'clean water and sanitation', 'affordable and clean energy', 'sustainable cities and communities' and 'industry, innovation and infrastructure'. Achieving the SDG's will require engineers to be innovative; an important requisite for innovation is a team that brings different points of view, different backgrounds and different approaches to the same problem (Middleton, 2016). Indicators of a diverse team include varied cultures, languages, ages, geography or personal hardships and gender (Page 2007).

The engineering profession in Australia is still a male dominated field; in 2016, women made up only 12.4% of the Australian engineering labour force (Engineers Australia, 2017) and in 2015 women represented only 17.6% of those commencing engineering and related technologies courses at Australian Universities (Department of Education and Training, 2017). Low interest in engineering from young people, especially women, will negatively affect the capacity of the engineering sector to meet global sustainability challenges (UNESCO, 2010). Meanwhile, research from across the university engineering education space including Bielefeldt, Paterson, & Swan (2009), Dzombak, Mouakkad, & Mehta (2016), and Oakes, Hsu, & Zoltowski (2015), suggests that linking STEM subjects to positive social impact leads to increased gender diversity in these courses. As engineers are being called on to contribute to the sustainable development agenda and the lack of gender diversity in the profession is being challenged, the opportunity exists to explore the links between these two priorities.

As an organisation with high gender diversity in its education programs and an explicit focus on social impact, Engineers Without Borders Australia (EWB) is well placed to further investigate the linkages between gender diversity and humanitarian engineering education initiatives with social purpose. As part of a broader study funded by the Origin Foundation, EWB is identifying how factors such as global relevance and social impact can be utilised by engineering educators to create a more diverse engineering profession. The first component of this research, and the work presented in this paper, focusses on determining if there is a difference in the motivations between men and women for participating in EWB programs that have an embedded focus on social impact. The paper first provides a background to the two humanitarian engineering education initiatives at the centre of this study and outlines the survey technique utilised to determine the motivations of participants of different genders. Results demonstrating similarities and differences in motivations between men and women are noted, and the relevance of this work to the broader study discussed.

For context, EWB is a member-based not for profit organisation with the vision that everyone has access to the engineering knowledge and resources required to live a life of opportunity, free from poverty (Engineers Without Borders Australia, 2017). Whilst EWB coordinates several engineering education initiatives in which university students elect to participate through either formal or informal curriculum, this paper focuses on two: the Humanitarian Design Summit Program and the University Research Program. These initiatives were chosen for this study as they are both programs to which students apply to participate, rather than embedded in the mandatory university curriculum. Students are not necessarily associated with EWB before they elect to participate in either program.

EWB Humanitarian Design Summits - Initiative A

Since January 2015, over 800 students have participated in the EWB-led Humanitarian Design Summits, Initiative A. The aim of this program is to nurture future development leaders and embed human-centred values and approaches in engineering, design and technology education. Six countries in the Asia-Pacific region provide the context for each immersive learning experience. Each Design Summit runs for two weeks and includes workshop sessions, cultural immersion activities and student-led investigations to help participants develop a deep understanding of the role Human-Centred Design (HCD) and technology play in creating positive change within communities. To deliver the program, EWB collaborates with numerous Australian Universities and partners closely with local grass-roots organisations that have a working relationship with communities. Since the recording of gender data began in mid-2016, 41% of program applicants and 45% of program participants have identified as female. The activities and structure of the program are described in more depth by (Brown, Price, Turner, & Colley, 2016) and by EWB (2017).

EWB University Research Program - Initiative B

Through final year research projects, the University Research Program, Initiative B, engages passionate academics and students to solve real-world problems in collaboration with development organisations who propose the research topic. In addition to developing new knowledge and technologies, students gain key engineering competencies as well as humanitarian skills. Research projects tend to be linked to partners working with marginalised or disadvantaged groups in the Asia-Pacific region under themes such as 'water and sanitation', 'clean energy', 'appropriate housing', 'assistive technology' and 'education and training'. Over the past 10 years, the University Research Program has seen a female participation rate of around 35-40%. The activities and structure of this program have been previously presented by Smith, Brown, & Cahill, (2009).

Approach

The first analytical component of the study, presented in this paper, assesses variations in motivations among participants in two humanitarian engineering initiatives: Initiative A and Initiative B. The objective was to explore similarities and differences in motivation between genders, and to determine if any variation is linked to the social impact of the initiative itself. It was determined that a relatively large sample size would be beneficial to enable the identification of potential variations, and as such a survey technique was employed for data collection.

To generate a discrete list of motivations for the survey, participants in Initiative A and Initiative B were asked to write open-ended statements describing their motivation for applying to that initiative. These motivation statements were coded, assessed and combined with input from individuals at the Centre for Ethical Leadership to inform the 24 distinct motivation statements (organised into six motivation categories) shown in Table 1. External input and additional deliberation meant that a slightly broader range of possible motivation statements were included in the final list. This was to mitigate any bias from the open-ended question respondents potentially skewing their answers in an effort to be perceived by EWB staff as holding more 'desirable' motivations for attending a program.

For this study, new participants in both initiatives who had not previously provided open-ended motivation responses were asked through a survey to identify their gender from four options: 'male', 'female', 'other', and 'prefer not to say'. Participants then selected the five motivation statements, from the list shown in Table 1, that had most resonated with them when applying to participate in the relevant initiative. For participants in Initiative A the motivation options, were presented in a consistent scrambled order whereas for Initiative B the motivation options were presented in the order shown in Table 1 with the motivation question inserted into an existing survey (with research consent obtained).

To mitigate bias the survey was distributed to participants after they had already been accepted onto the relevant program. Additionally, participants in Initiative A were invited to remain anonymous and participants in Initiative B were informed that their responses would not affect their place on the program, however it is noted that not being anonymous may have introduced a slight bias to stated motivations. Integrating the motivation question into an existing survey for Initiative B reduced the administrative load on the participants which resulted in a response rate of 71%. Whilst this high response rate may indicate a self-selecting group, anecdotal feedback from academic supervisors suggests these students tend to be highly driven and engaged.

Table 1: List of possible motivations

Motivation Category	Motivation
Values	Wanting to give back to the community
	The possibility of making positive social changes
	Work directly with and help people who might be disadvantaged
	Inspired from personal experience to make a difference
Career	Gain relevant work experience
	Build up your CV
	Kickstart a career in humanitarian work
	It is a way to earn course credits towards your degree
	Expand engineering knowledge
	Make new connections that might help your career
Social-Connectedness	Know EWB and just want to continue to be involved with EWB
	Looking for an opportunity to connect with like-minded people
	Looking for a way to feel connected with different people
Social Pressure / Encouragement	My parents have encouraged me to participate in this kind of program
	My friends have encouraged me to participate in this kind of program
	Other with whom I am close place a high value in this kind of program
Understanding	It is an opportunity to learn about, from and experience different cultures
	Learning about and applying humanitarian engineering
	Experience developing-world issues first hand
	Understanding how engineering works in the real world
Enhancement	Looking for an opportunity to put what you know into practice
	Being able to develop personal skills
	Gain leadership skills
	Looking for a truly challenging task

The differences between the two initiatives chosen for this study provide an opportunity to check that any variations in motivation between participants of different genders was not purely based on the ‘type’ of initiative chosen. The major differences include participants’ year of study, program location/duration, the course credit obtained. Initiative A is open to students from any year group whereas Initiative B is only available to final year students who mostly graduate upon completion. Students participate in Initiative A for two weeks overseas with the experience mainly counting towards required industry experience while Initiative B lasts between one and two semesters, is mainly based at the student's university (with potential for field work) and must be part of a for-credit course or unit.

Results and Discussion

This paper discusses the first set of motivation results from students participating in Initiative A and Initiative B.

Motivations for participation in Initiative A

Seven deliveries of Initiative A were completed over the period February to July 2017 during which 195 students completed the motivation survey. Of these, 103 identified as 'male' (representing 53% of responses) and 92 identified as 'female' (representing 47% of responses). No respondents selected a gender of 'other' or 'prefer not to say'. For this initiative, there were a relatively high number of responses, balanced across genders. As each respondent was asked to select exactly five motivations, 975 individual motivations were collected. Table 2 shows the distribution of these motivations across the six categories outlined in Table 1 as well as the percentage of participants selecting at least one motivation in each category.

Table 2 Distribution of motivations for participation in Initiative A

	% of total responses			% of participants selecting at least one motivation		
	Male	Female	**Female Swing**	Male	Female	**Female Swing**
Values	21	23	**+2**	72	76	**+4**
Career	25	18	**-7**	79	63	**-16**
Social-Connectedness	8	10	**+3**	32	46	**+14**
Social Pressure / Encouragement	2	1	**-1**	8	4	**-4**
Understanding	28	33	**+6**	88	94	**+6**
Enhancement	18	15	**-3**	64	59	**-5**

As can be seen from Table 2, the 'understanding' category contained the greatest proportion of selections for both female and male respondents, with 94% of female respondents selecting at least one of the motivations in this category.

The top three motivations, split by gender, are shown in Table 3.The top three motivations for both male and female respondents were extremely similar, suggesting that the major motivations for respondents to participate in the initiative did not depend on gender but rather the stated purpose of the initiative. Additionally, the data shows that a greater proportion of female respondents selected a 'social connectedness' motivation than male respondents with the reverse true for a 'career' motivation. Overall, both male and female participants in Initiative A are primarily motivated by statements in the 'understanding' category; across all motivation statement categories relatively large gender differences are seen in two, male respondents are more aligned to 'career' and female respondents to 'social connectedness'.

Table 3 Top three motivators by gender for Initiative A

Female		Male	
Motivation	% of total responses	Motivation	% of total responses
Learning about and applying humanitarian engineering (U)	12	Learning about and applying humanitarian engineering (U)	8
It is an opportunity to learn about, from and experience different cultures (U)	11	The possibility of making positive social changes (V)	8
The possibility of making positive social changes (V)	10	Experience developing-world issues first hand (U)	7

Motivations for participation in Initative B

Of the 52 participants entering Initiative B between December 2016 and August 2017 who responded to the motivation survey, 38 identified as 'male' (representing 70% of responses) and 14 identified as 'female' (representing 30% of responses). No respondents selected a gender of 'other' or 'prefer not to say'. Whilst this dataset is not as balanced as that for Initiative A, it provides a useful initial insight into student motivations. Again, each respondent was asked to select exactly five motivations resulting in the collection of 260 individual motivations. Table 4 shows the distribution of these motivations across the six categories outlined in Table 1 as well as the percentage of participants selecting at least one motivation in each category.

Table 4 Distribution of motivations for participation in Initiative B

	% of total responses			% of participants selecting at least one motivation		
	Male	Female	**Female Swing**	Male	Female	**Female Swing**
Values	32	39	**+7**	92	93	**+1**
Career	25	20	**-5**	77	71	**-6**
Social-Connectedness	6	10	**+4**	32	50	**+18**
Social Pressure / Encouragement	0	0	**0**	0	0	**0**
Understanding	22	27	**+5**	74	71	**-3**
Enhancement	15	4	**-11**	61	21	**-40**

Both male and female respondents in Initiative B strongly identified with motivation statements in the 'values' category. For both genders, at least 92% of participants selected at least one 'values' motivation statement. No participant reported being motivated due to social pressure or encouragement. The top three motivational responses for Initiative B are shown in Table 5.

Table 5 Top three motivators by gender for Initiative B

Female		Male	
Motivation	% of total responses	Motivation	% of total responses
Wanting to give back to the community (V)	13	The possibility of making positive social changes (V)	16
The possibility of making positive social changes (V)	11	Learning about and applying humanitarian engineering (U)	8
Learning about and applying humanitarian engineering (U)	10	Expand engineering knowledge (C)	7

For male respondents ‘the possibility of making positive social changes’ in the values category was the most popular response (31 selections comprising 16% of responses), almost double that of the next most popular motivation which was ‘learning about and applying humanitarian engineering’ (16 selections comprising 8% of responses) in the understanding category. Two motivation statements appear in the top three selections for both female and male respondents, again suggesting that there is no significant gender difference in the primary motivation for participation in this initiative.

When looking at the differences between the genders, male respondents select a greater portion of motivations in ‘career’ and ‘enhancement’ categories while female respondents skew towards ‘values’, ‘understanding’ and ‘social-connectedness’. By looking at respondents who select at least one motivation in that category a larger disparity is observed; female motivation skewing towards ‘social connectedness’ and away from ‘enhancement’; even though enhancement was not a popular male response it was still higher than that of female selection. The results show that all participants in this initiative are motivated by an alignment of ‘values’. When looking in more detail at participants selecting at least one motivation in each category female respondents have a skew towards ‘social-connectedness’ and away from ‘enhancement’.

Insights from a comparison of responses

The most popular motivation category for both male and female respondents participating in Initiative A is ‘understanding’ whereas for Initiative B for both male and female respondents it is ‘values’. The motivations in these categories are consistent with the aims of the respective program; Initiative A is tailored more towards experiencing humanitarian engineering in an immersive hands-on experience while Initiative B is more aligned to taking acquired knowledge and applying it in a humanitarian project. The second most popular motivational category for each initiative was the same as the most popular category for the other initiative showing that motivations across initiatives is relatively similar.

Of all the individual motivation statements, ‘learning about and applying humanitarian engineering’, and ‘the possibility of making positive social changes’ appear in the most popular three motivations for both genders across both initiatives, suggesting students have similar motivations for engaging with EWB irrespective of the particular engineering education initiative.

For both initiatives, female respondents tended to select ‘social connectedness’ motivations more frequently than their male counterparts. In contrast, male respondents in both initiatives were more likely to select motivations in the ‘career’ (Initiative A) or ‘enhancement’ (Initiative B) categories. Looking at differences in gender for these initiatives, female respondents do tend to have a stronger alignment to motivations around social connectedness including ‘looking for a way to feel connected with different people’ as well as ‘looking for an opportunity to connect with like-minded people’.

Of the motivation statements used in this study it is those in the ‘values’ category that are most aligned with the notion of having ‘social impact’. For both initiatives in this study female respondents included a greater number of selections in this category which suggests that female respondents may be slightly more motivated to participate in engineering education initiatives for reasons of social impact.

Opportunities and imperative for furthering the research

The initial findings presented in this paper provide a basis for further investigation into the relationship between engineering education initiatives with a humanitarian focus and a diverse university engineering student cohort. The two initiatives discussed are currently attracting a significantly higher proportion of women compared to the engineering discipline more broadly. These initiatives provide a rich context to begin to understand the implications of humanitarian engineering offerings on diversity in the classroom as both humanitarian engineering and gender diversity become increasingly prioritised at Australian universities. As an example, in both Initiative A and Initiative B female respondents related more than their male counterparts to motivations in the ‘social connectedness’ category. The motivation statements in this category, such as ‘looking for a way to feel connected with different people’ (see Table 1), do not specify only feeling connected to other participants of the same gender. It is possible that participants are looking to connect with a community defined by something common to humanitarian engineering education initiatives; this is to be investigated in future research.

Further research to support confidence in these initial findings, using additional methods and techniques, is currently planned or already underway. This includes interviews with a selection of respondents to understand how participants have understood and perceived each of the motivational categories and to generate further insights. Data has also been collected in which selected motivation statements are ranked, analysis of which could provide insights into the primary motivator of each participant compared to what may be secondary motivations. Comparisons of these findings can be made against the analysis presented in this paper.

Additionally, while the research described in this paper focuses on diversity using a gender lens, the opportunity exists to use similar mechanisms and datasets to further investigate the relationship between humanitarian engineering education initiatives and other forms of diversity which will create more creative, innovative engineering teams in the future.

Conclusions

This paper takes the initial step of identifying student motivations for opting-in to engineering education initiatives with a humanitarian focus, and exploring any differences in responses between genders.

The data collected indicates that the most common motivator for participating in two of EWB’s initiatives does not vary with gender, instead, and unsurprisingly, it is strongly aligned to the aims of that initiative. However, when looking across the whole dataset the popularity of motivations does vary by gender. In general, male respondents tended towards motivators in the ‘career’ and ‘enhancement’ category more than females, while female respondents tended towards motivators in the ‘social connectedness’ category more than males. This research is an initial indication of trends and further work is required for confirmation.

To establish a deeper understanding of this issue, further work is planned to create a methodology that can be used to study diversity in other forms.

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Explicitly teaching teamwork and written communication within a problem based curriculum: Development of a generalised framework

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SESSION
C1: Integration of theory and practice in the learning and teaching process

CONTEXT
Recent years have seen the growing importance of employability skills for engineering graduate success. Beyond disciplinary specific capabilities, employers increasingly expect graduates to be proficient in skills that are transferable across employment contexts; specifically, “the ability to communicate, collaborate and operate effectively within an industry environment” (Deloitte Access Economics, 2014, p. 3). However, there are concerns that current undergraduate programs, both in Australia and internationally, are producing graduates without the requisite proficiency in employability skills to flourish in their profession. According to the European Commission (2015), “the successful development of [employability] skills requires an education system capable of preparing students through more active and problem-based learning approaches, using assignments from the ‘real world’ and including support for risk taking and creativity” (p. 4). Nonetheless, within a problem based curriculum, skills development must be explicit. In particular, teamwork skills are “not likely to emerge spontaneously” (Hughes and Jones, 2011, p. 60). Effective implementation of explicit skills development within a problem based learning environment (PBL) remains an open research question.

PURPOSE
This paper reports on the development of a generalised pedagogical framework for explicitly scaffolding written communication and teamwork skills within a PBL curriculum.

APPROACH
Over several years, employability skills development within an Australian mechanical engineering degree program was evaluated using curriculum mapping, student performance, and staff and student feedback. This evaluation reviewed employability skills needs of graduates, and investigated why such skills were being underdeveloped within the curriculum, despite widespread application in learning and assessment tasks. Evaluation findings informed the development of a pedagogical framework, designed to explicitly address the employability skills shortfall within a PBL curriculum.

RESULTS
The study highlighted that the development of written communication and teamwork skills were largely assumed within the engineering degree program. Learning modules or experiences devoted to developing these skills were either rare (as with written communication) or largely absent (as with teamwork). Additionally, many large projects utilising these skills comprised a single, culminating assessment task, without opportunity for students to reflect on skills development or apply instructor feedback from one task to the next. Hence, a PBL subject structure was developed, integrating explicit instruction on written communication and teamwork, and allowing scaffolded reflection and performance enhancement within a single teaching period to assure learning.

CONCLUSION
The PBL framework intentionally scaffolds written communication and teamwork skills within a single subject, making possible accelerated and contextualised employability skills development. This framework has applicability across subjects, year levels and disciplinary contexts.

KEYWORDS
PBL; teamwork; written communication; employability skills; pedagogical framework.

Introduction

International trends in higher education have seen growing emphasis on embedding employability skills within curriculum (Arkoudis, Baik, Bexley, and Doughney, 2014; Scott, 2016; Yorke, 2006; Yorke and Knight, 2006). Beyond disciplinary-specific knowledge and skills, graduates are increasingly expected to be proficient in a range of skills that are widely applicable and transferable across employment contexts and suitable for life-long learning (Matthews and Mercer-Mapstone, 2016; Office of Parliamentary Counsel, 2015). Recent research into Australian employer perceptions revealed the critical role of employability skills for STEM graduates – in particular, “the ability to communicate, collaborate and operate effectively within an industry environment” (Deloitte Access Economics, 2014, p. 3). Nonetheless, there remain concerns both within Australia and worldwide that current undergraduate programs are producing graduates without the requisite proficiency in employability skills to be successful in their profession (Arkoudis and Doughney, 2014; Norton, Sonnemann, and Cherastidtham, 2013; Shah and Nair, 2011). The 2014 European Union (EU) Skills Panorama report highlighted findings from employer surveys, indicating that a proportion of STEM graduates exit universities under-skilled in communication, team-working and time management and organisational skills (European Commission, 2015, p. 4).

The current shortfall in employability skills development has led to broad calls and legislative imperatives for curriculum reform (Office of Parliamentary Counsel, 2015). Systematic approaches to teaching and assessing such skills within the context of the discipline, however, present challenges for academics (Arkoudis and Doughney, 2014; Arkoudis, 2014; Matthews and Mercer-Mapstone, 2016). Widening participation in higher education has meant that academics engage students with more diverse educational backgrounds and levels of preparedness for academic studies (Arkoudis and Doughney, 2014; Norton et al., 2013). While the research literature indicates that academics are concerned about their students’ communication skills, they do not believe they have the time and expertise to address explicit skills development within curriculum (Baik, 2010; O’Loughlin and Arkoudis, 2009). More holistic pedagogies appear to be needed but their implementation cannot come at the expense of the disciplinary-specific fundamentals that underpin any career in STEM.

According to the European Commission (2015), “the successful development of [employability] skills requires an education system capable of preparing students through more active and problem-based learning approaches, using assignments from the ‘real world’ and including support for risk taking and creativity” (p. 4). The implementation and benefits of active learning pedagogies for disciplinary-specific skills development in the STEM fields are well documented (de Graaff, 2004; Frank, Lavy, and Elata, 2003; Mills and Treagust, 2003). Active approaches like problem based learning (PBL) have been shown to improve student engagement, student achievement, and skills retention (Freeman et al., 2014; Prince, 2004). However, an intrinsic link between PBL and improved employability skills, such as communication and teamwork, is less well established.

Kashefi, Ismail, and Yusof (2012) investigated the effectiveness of blended learning strategies, including active group tasks, on developing communication and teamwork skills within a multivariable calculus engineering subject. While they identified a modest improvement in students’ communication skills throughout the subject, they saw no difference in students’ teamwork skills, despite the variety of group tasks. Frank et al. (2003) reviewed implementation of PBL within a freshmen engineering subject and similarly found that team performance was poor in the absence of formal instruction in teamwork skills. A variety of other researchers (Colthorpe, Rowland, and Leach, 2013; Loughlin, 2013; Mort and Drury, 2012) agree that communication and teamwork skills must be intentionally developed within any active learning experience to achieve meaningful improvement. In particular, effective teamwork skills are “not likely to emerge spontaneously” (Hughes and Jones, 2011, p. 60.). There is extensive research literature that outlines strategies for explicitly teaching English language skills (e.g. Arkoudis 2014; Arkoudis and Doughney 2014; Colthorpe et al.

2013; Mort and Drury 2012) and teamwork skills (Hughes and Jones, 2011; Loughlin, 2013; Loughry, Ohland, and More, 2007; Page and Donelan, 2003; Riebe, Roepen, Santarelli, and Marchioro, 2010). While syllabus level frameworks like the CDIO (Crawley, Malmqvist, Lucas, and Brodeur, 2011) outline best practice with respect to a PBL focussed engineering curriculum, there remains a gap in the research on how to specifically structure effective employability skill development within a single PBL subject.

The development and evaluation of a pedagogical framework that specifically embeds formal written communication and teamwork skills development within a problem based curriculum will be the focus of this paper. The framework has been developed and implemented within a first-year introduction to engineering subject, but has applicability across university subjects, disciplines, and year levels. The remaining sections of this paper detail the curriculum evaluation that led to the development of the framework, outline the framework itself, and provide preliminary conclusions on the effectiveness of the approach.

Curriculum Evaluation

The pedagogical framework developed in this work emerged and evolved over several years in response to specific skills gaps identified within the curriculum of an Australian mechanical engineering degree program. The skills shortfall was highlighted by the significant challenges many later-year engineering students experienced when undertaking team-based project work, despite having completed numerous team-based learning tasks in preceding subjects. Challenges largely arose due to poor application of fundamental teamwork skills, including communication; time, task, and document management; and meeting organisation protocols. It became apparent that the requirement for students to work in teams throughout their degree was not sufficiently building their capacity for effective teamwork.

Upon further inspection, it was also apparent that elements of written communication skills development were implemented unsuccessfully throughout the curriculum. Unlike teamwork skills, modest improvements in written communication were evident during progression, but these improvements were considerably less than expected given the prevalence of written assessment throughout the program. It became clear that the strategies employed to develop key employability skills within the mechanical engineering program were either ineffective or inefficient, and further investigation was needed.

As part of a whole-of-program review, a detailed mapping exercise was carried out following the process of Holmes, Sheehan, Birks, and Smithson (2017). Metrics relevant to teamwork and written communication skills development are highlighted in Table 1. A significant disconnect between instruction and assessment is evident. In addition, it was found that assessment of teamwork and written communication occurred through many small tasks or elements of larger tasks, with limited opportunity for deep and authentic evaluation of skills development. The mapping exercise highlighted a clear need to better align instruction and assessment within subjects, and to develop and assure skills in a progressive and coherent way across the whole-of-program (Nightingale, Carew, and Fung, 2007; Orey, 2010).

Table 1: Curriculum mapping results specific to teamwork and written communication skills development (based on evaluation of the 28 subjects in the mechanical engineering major).

Employability skill	Number of subjects with formal instruction on skill	Total hours of formal instruction on skill	Number of subjects with specific assessment on skill	Proportion of all assessment in mech. eng. major devoted to skill
Teamwork	1	0.2	13	1.87%
Written Communication	3	3	21	7.21%

Learning experiences typically unfold in stages. Hughes and Jones (2011) identified teaching, practice, and feedback stages. Fink (2013) outlined an holistic view of active learning, involving three aspects: i) information and ideas, ii) experiences, and iii) reflection. Combining these elements, we propose the recursive four-stage process of Figure 1. Here, theory, practice, assessment and feedback, and reflection are identified as key elements of learning. Notably, the repetition of the learning process realises increasing complexity and depth. In this way, scaffolding of a skill or competence is achieved.

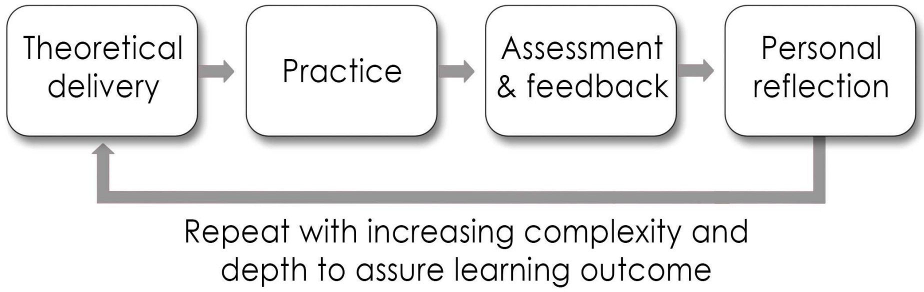

Figure 1. Flowchart representing an effectively staged and scaffolded learning process.

Importantly, within many subjects in the focal mechanical engineering program, assessment of skills was observed to occur through a single culminating assessment task (such as a project). While the full recursive learning cycle was assumed by academic staff to be occurring over a sequence of multiple subjects, there was little evidence to support this assumption. Both the findings of the curriculum review (Table 1), and the skills gap demonstrated by later-year students suggested to the contrary. As such, it was determined that curriculum changes were necessary to ensure appropriate skills development, and that intentional and effective scaffolding should feature as a key aspect of the redevelopment.

While comprehensive, program-wide redevelopment was attractive, it was infeasible in the context. Instead, improvement of key subjects was chosen as the most effective solution. In the first instance, the first-year introduction to engineering subject was chosen for redevelopment to address the skills shortfall and better prepare students to successfully engage with subsequent program work. Problem based learning (PBL) (Mills and Treagust, 2003) was chosen as the primary pedagogical approach for the subject. In the process, a generic framework for scaffolding teamwork and written communication skills within any single PBL subject emerged; the framework is presented in the following section.

Pedagogical Framework

The proposed pedagogical framework intentionally scaffolds teamwork and written communication skills development alongside the disciplinary-specific content of a PBL subject. This scaffolding is achieved through focussed learning activities and two consecutive projects (Figure 2). Importantly, all learning in the subject occurs within the context of these two projects. With a view to broader application of the framework, it is anticipated that the balance of independent learning and prescribed teaching is context-dependent, based on the complexity of the subject's theoretical content and ability of the students. For example, Figure 2 shows a full suite of face-to-face classes (lectures, tutorials, and practicals) as appropriate for a first-year class where students are still developing independent learning skills. Higher-level subjects may reduce such class time in favour of more independently driven PBL. Either way, it is intended that instruction focuses on the development of both disciplinary-specific skills and the targeted employability or generic skills, to enable students to successfully engage with project activities. The projects are intended to be completed by students in teams. Teams are required to submit an associated report, and potentially produce an additional output like a design, performance, presentation, etc. It can be seen in Figure 2 that a select number of classes are devoted to explicitly teaching the teamwork and written communication aspects of the project.

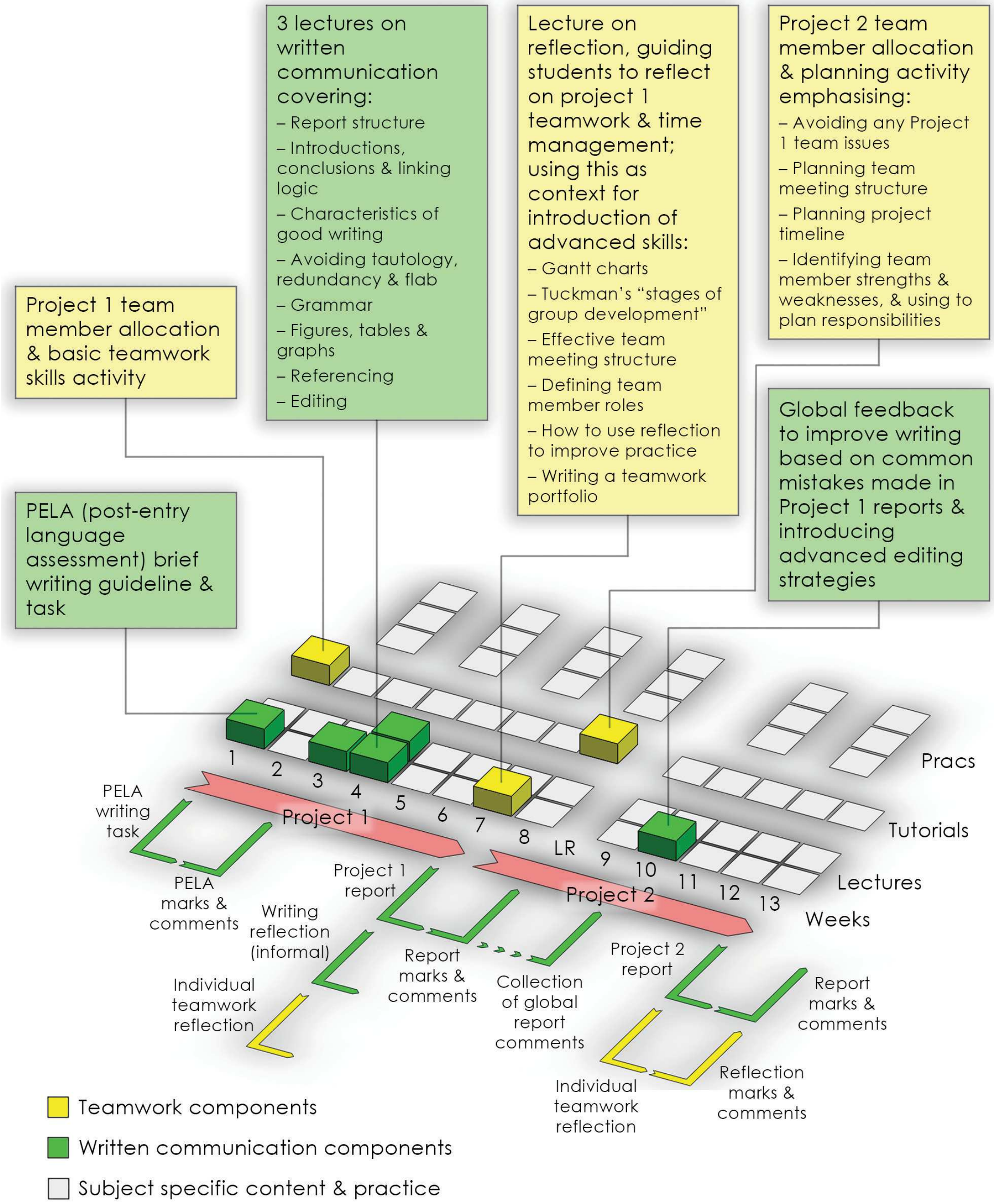

Figure 2. PBL subject structure for explicit scaffolding of written communication and teamwork skills (note LR refers to lecture recess and is a mid-semester break from formal teaching).

The two projects are intentionally staged in terms of the level of instructor guidance provided, and the complexity of the tasks. Classes are used to guide students through each project phase explicitly. In the case of a first-year implementation of the framework, a diagnostic post-entry language assessment (Arkoudis, 2014) is a valuable starting point to identify students that need additional writing assistance at the outset. Throughout the first project, an introduction to basic teamwork skills session is provided, and a set of written communication skill lectures is given in the middle of the timeline, as students are beginning to write their project report. Upon completion of project 1, a dedicated lecture instructs students on how to reflect on their performance, particularly in terms of teamwork, as well as to provide tools to improve the effectiveness of team meetings, management, and distribution of labour (see Loughry et al. 2007; Page and Donelan, 2003; Riebe et al. 2010; Woods et al. 2000). The students must also write an individual teamwork reflection focussing on their own performance as a team member against several important categories (Loughry et al. 2007).

For project 2, students are assigned new teams and given an opportunity to formally plan with their new team members how to capitalise on teamwork successes, and avoid the mistakes, of the first project. Project 2 focusses on a more complex and demanding task but may follow a similar procedure to project 1. Students are expected to demonstrate a higher level of creativity and independence compared to the first project and, as such, classes focus on advanced topics and skills. Importantly, feedback on the first project report is used as a mechanism to improve students' written communication skills in the second report. In addition to marks and comments provided for the first project report, a global feedback lecture is given identifying common mistakes and areas for improvement. Advanced editing skills are also outlined at this point (note, editing is generally observed as the area needing the greatest improvement after the first report). Again, this lecture is provided as students enter the writing phase of project 2. Upon project completion, students again submit a team report and a formal individual reflection on their personal teamwork performance. In this case, both the group report and individual reflection are marked and comments provided.

Assigning individual marks for group-based activities is a major challenge for academics and a cause of anxiety and animosity among students (Colthorpe et al. 2013; Riebe et al. 2010). In the proposed framework, marks are determined differently for the two projects. Given that the first project is heavily guided, and students complete much of the work during class time, each student in a team is assigned the same report grade (assuming sufficient class attendance). For the second project, which is conducted predominantly outside of class time, students complete a weekly timesheet detailing their project-related work hours. Each student must have their timesheets signed-off by all other team members on a weekly basis. Individual marks are calculated by scaling the group report mark based on individual contributions. This scaling sees hard working students receive higher marks, and less committed students, lower marks. Scaling can be simple and based on cumulative hours alone, or complex and based on hours contributed to an aspect of the project and the weighting assigned to that aspect. The introduction of a mechanism to identify and manage relative commitment and investment on the part of individual team members, and to provide assurances that those who complete the most work will achieve the best mark, ameliorates underlying animosities that accompany teamwork, or at least identifies and addresses tensions early. Timesheets also mirror how work is often measured in professional practice, adding a further 'real-world' feature to project activities.

The distinguishing feature of the proposed framework is the embedding of two complete cycles of the learning process, depicted in Figure 1, within a single subject. All four learning elements (i.e. theoretical delivery, practice, assessment and feedback, and reflection) are contained within each project cycle. So too, the enhanced complexity of project 2 ensures a scaffolding of targeted employability skills. Similar scaffolding and impact on student learning and achievement can be realised for the discipline-specific dimensions of the project work.

Conclusions

Implemented within a first-year introduction to engineering subject, initial evaluation of the developed PBL framework has seen it accelerate development of both employability and disciplinary-specific skills. While student consultations to address group issues had been common in the past, the improvement in student team skills has resulted in far less need for instructor intervention. In terms of written communication skills, clear improvements in quality, editing, and conciseness have been observed, with an evident increase in the class average mark for project 2. Quality of design work also consistently exceeds expectations. An enhanced student experience has also been observed with significant improvement in formal student survey scores, and excellent informal feedback on teamwork and the group projects generally. Formal evaluation of the effectiveness of the proposed pedagogical framework is presently underway and will be published in the future.

Following on from the initial success of the framework, advanced variants have since been implemented in later year design subjects, with a similarly positive impact on student outcomes. While currently in pilot implementation among the authors, the framework has also been packaged as an institutional exemplar of good practice within JCU professional development activities [link]. In this context, the approach has been positively received by academics from across the university, and enthusiasm is frequently expressed for a PBL structure that is conceptually simple and effective in employability skill development.

The framework developed in this work has been found to be a powerful way to deliver employability and discipline-specific skills development within a single PBL subject.

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Student Expectations:
The effect of student background and experience

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CONTEXT

The perspectives and previous experiences that students bring to their programs of study can affect their approaches to study and the depth of learning that they achieve (Prosser & Trigwell, 1999; Ramsden, 2003). Graduate outcomes assume the attainment of well-developed independent learning skills which can be transferred to the work-place.

PURPOSE

This 5-year longitudinal study investigates factors influencing students' approaches to learning in the fields of Engineering, Software Engineering, and Computer Science, at two higher education institutes delivering programs of various levels in Australia and New Zealand. The study aims to track the development of student approaches to learning as they progress through their program. Through increased understanding of students' approaches, faculty will be better able to design teaching and learning strategies to meet the needs of an increasingly diverse student body. This paper reports on the first stage of the project.

APPROACH

In August 2017, we ran a pilot of our survey using the Revised Study Process Questionnaire (Biggs, Kember, & Leung, 2001) and including some additional questions related to student demographics and motivation for undertaking their current program of study. Data were analysed to evaluate the usefulness of data collected and to understand the demographics of the student cohort. Over the period of the research, data will be collected using the questionnaire and through focus groups and interviews.

RESULTS

Participants provided a representative sample, and the data collected was reasonable, allowing the questionnaire design to be confirmed.

CONCLUSIONS

At this preliminary stage, the study has provided insight into the student demographics at both institutes and identified aspects of students' modes of engagement with learning. Some areas for improvement of the questionnaire have been identified, which will be implemented for the main body of the study.

KEYWORDS

Student expectations; student approaches to learning; student demographics

Student Expectations: The effect of student background and experience

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Introduction

Although universities claim to produce ‘work ready’ graduates (DEST, 2005; Orrell, 2004) especially as measured by their graduates’ capacity to obtain a full-time job related to their field of study, a recent survey by the Australian Information Industry Association (AIIA) revealed that overwhelmingly their members identified a “job ready skills gap” (AIIA, 2017). Students may be competent in a specific skill in one setting, such as university assessment, but frequently they are unable to put that skill to use in another (Prosser & Trigwell, 1999).

Supporting the AIIA findings, recent work in New Zealand, funded by the Engineering Education to Employment organisation (EE2E), has shown that employers believe students of Institutes of Technology and Polytechnics (ITPs) are more likely to have job ready skills. This research reported the “consensus was that ITP graduates have a better range of emotional intelligence capabilities and are more ‘work-ready’ than their university-qualified peers” (EE2E, 2015). EE2E are currently working to increase the number of ITP graduates to meet projected demand for future growth in New Zealand.

Educational research has shown that learning transfer to unfamiliar problems and environments happens best when the learner has “developed a deep, rather than surface, understanding” of the problem (Barnett & Ceci, 2002, p. 616). Despite this, within tertiary education and society more generally, there is a focus upon quantitative rather than qualitative learning, where quantitative learning is described as learning that can be ‘measured’ or where there is a ‘right’ answer and qualitative learning is where learners are able to identify the connections between various aspects of their learning and so can put together those aspects into a new pattern better suited to the problem they are currently working on (Dahlgren, 1997; Entwistle, 1997; Prosser & Trigwell, 1999; Ramsden, 2003).

Furthermore, it has been shown that the perspectives and previous experiences students bring to their programs of study influence their approaches to study which in turn affects the depth of learning that they achieve (Prosser & Trigwell, 1999; Ramsden, 2003). A learner’s ability to learn is affected by their understanding of the context of the learning. Additionally, their prior knowledge affects their perception of the context: those with a well-developed understanding are more likely to perceive the context such that it affords deep learning, while those with poor prior knowledge perceive the context so that it affords surface learning (Prosser & Trigwell, 1999).

As problem- and project-based learning (PBL) has been shown to help students gain a deeper understanding than other approaches offer (Hmelo-Silver, 2004; Wood, 2003), many higher education institutions teaching engineering and computing have introduced PBL. This approach has been a key philosophy in many of the ITP’s in New Zealand and in the Australian tertiary sector where a need has been identified for graduates with good practical skills. Because PBL focuses on ‘why’ an approach is important rather than ‘how’ to do something it leads to learners memorising for understanding, rather than simply memorising to pass a test. This learning and teaching approach specifically focusses on providing graduates with the necessary skills for work.

The seeds for this research project were sown by Michael Prosser during his keynote address at the 2016 Annual Conference of the Australasian Association for Engineering

Education (AaeE) (Prosser, 2016). During his presentation, Prosser suggested that there would be value in applying Biggs' Study Process Questionnaire (Biggs, Kember, & Leung, 2001; Zeegers, 2002) across different courses with the same students, as well as to students in their first and last year of study, suggesting such an approach would produce a good view of the variation across the field.

Prosser's challenge, and accepting that "explanations that might fairly reflect and give insight into student experiences require an understanding of the complex context in which learning occurs" (Kieser, Herbison, & Harland, 2005), have shaped our research design.

Methodology

This research will follow different cohorts of students throughout their time of study to see whether their expectations and prior experience coming into a program affects how they study, and whether there is a change in expectations or learning style as their study progresses. Each year a process of data collection will occur and will continue until all cohorts complete their period of study. Ethics approval has been granted at each institution for this research program to be undertaken.

The Cohorts

Participants in this study were drawn from the cohorts of students enrolled in engineering and computing programs of study at two tertiary institutions, one in Australia and the other in New Zealand. These institutions were chosen so that a range of levels of qualification and background and experience could be targeted. Although both institutions have roughly the same number of students (about 20,000 in total) and academic staff (just over 800), they are substantially different. The first is an internationally-ranked, world-leading, research-intensive university located in a capital city with a participant cohort of around 2,500, while the second is a local, teaching-focused, vocational institute with a participant cohort of around 500 students.

As shown in Table 1 below, the research targets a range of different qualifications, from level 6 to level 9 on the New Zealand Qualification Framework (NZQF) (New Zealand Qualifications Authority, n.d.) and the Australian Qualification Framework (AQF) (Australian Qualifications Authority, n.d.). In New Zealand, students are enrolled in 2- and 3-year undergraduate Civil, Electrical or Mechanical Engineering study programs. In Australia, students are enrolled in several Engineering or Computing study programs at both undergraduate and post-graduate level. (See endnote for program names.)

Table 1: Student cohorts included in this study

Qualification [i]	NZQF& AQF Level	U/G or P/G	Duration of study program (years)	Percent of total cohort at each institution		Age range
				Aus.	NZ	
NZDE	6	U/G	2		66%	19-34
DCOMP	6	U/G	1	3%		19-20
BEngTech	7	U/G	3		34%	20-42
BIT, BADA	7	U/G	3	15%		18-25
BIT(Hons), BAC, BSENG	8	U/G	4	21%		17-48
BE	8	U/G	4	37%		18-50
GCert/GDip	8	P/G	1	4%		19-47
MENG	9	P/G	2	6%		20-57
MCOMP, MADA	9	P/G	2	14%		21-56

Data collection

The data for the longitudinal study will be collected using a range of tools:

1. A survey which includes the Revised Student Study Questionnaire from Biggs et al. (2001). This instrument will be the first tool used and will collect as much information as possible, from which to develop the themes and correlations. To do this the survey will include Likert type questions as well as open ended qualitative questions.
2. Once themes have been identified, focus groups and interviews will be used to further explore areas of interest.
3. Student attendance and performance, as provided by students through a series of questions in the survey, will be collected to help understand whether the learning styles are being reflected in the quality of student work, attendance, and marks.

At the beginning of semester 2, 2017 the survey was piloted with the currently enrolled cohort of students. The aim of this initial survey was to ensure that the survey design was appropriate and the data collected reasonable. The longitudinal study will start in Semester 1, 2018 and will run until 2022 (see Table 1 above).

Design of Questionnaire

Data was collected from participants via an anonymous online questionnaire which included the complete Revised Study Process Questionnaire (RSPQ) developed by Biggs et al (2001) with additional questions to investigate respondents' demographics, motivations, and their development of professional skills. Respondents' anonymity was preserved using a structured, self-generated identifier: a concatenation of the first three letters of the student's mother's name, the year of the student's birth and the first three letters of the student's first name. This identifier preserves anonymity, while allowing longitudinal comparisons of data from participants in successive instances of the survey.

The questionnaire was organised in three sections: (1) demographic data, (2) motivation for studying, and (3) approaches to learning, and consisted predominantly of questions requiring Likert-scale ratings, with limited opportunity for unrestricted responses. The overall research design anticipated that areas needing in-depth analysis would become the topic for focus group sessions in future stages of the research. The estimated time to complete the questionnaire for a native English language respondent was less than 10 minutes. This falls within the recommended 20-minute questionnaire limit for respondent data reliability (Cape & Phillips, 2015). To reduce respondent drop-out rate, the online questionnaire system was suitable for both PC and mobile device use (Cape & Phillips, 2015).

Section (1) 'demographics' included the seven most relevant of the 26 questions in Dowling's (2010) survey of Australian para-professional engineering students. The questions asked respondents to identify their *enrolled program of study, gender, age, responsibilities in the two years prior to this period of study, semester of study, ethnicity, and domestic/international status*.

Section (2) 'motivation for study' prompted respondents to rate a set of eight possible motivators on a five-point ordinal Likert-scale (Sullivan & Artino, 2013). The prompts were: *to get a high-paying job; to learn things that I'm interested in; for my family; to get an interesting job; because I'm good at this; because it's fun & exciting; to make an impact on my community / country / the world; to help me gain residency*. Collecting this data on the participants' motivations for study allowed an investigation into a possible correlation between background and prior experience and the approach students took to learning in their program of study. This approach is similar to Dowling's (2010) survey, which also asked respondents to report on motivations to study using Likert-scale responses.

Section (3) 'approaches to learning' contained 31 questions using Likert-scale ordinal ratings to understand how frequently students employ deep or surface approaches and attitudes to learning. This section included the 20 RSPQ questions (Biggs et al., 2001) and an additional 11 questions seeking to understand students' use of learning resources, time management and teamwork skills. The survey used the RSPQ scale; *Never/almost never; Sometimes; About half the time; Often; Almost always/always (*Biggs et al, 2001). Biggs et al. (2001) provide a 50-point scoring system for the ten questions related to each approach, to evaluate a respondent's preference for deep or shallow approaches to learning. The validation procedure for the set of questions and analysis method used by Biggs et al. (2001) is described in their paper and gave the authors of this study confidence in using the RSPQ as a reliable tool to evaluate respondents' approaches to learning for this piece of research. The data from the additional questions will be used independently to investigate potential correlations with factors from earlier sections of the survey, and to identify whether students are developing skills for the work environment.

To evaluate the usefulness of the data collected, the authors conducted an initial, basic analysis of the data and a reflection on the tool used for data collection and it is this which is reported in this paper.

Results and Discussion

As well as commenting on the demographic data collected, we report on data from a single question, chosen because it provides an interesting snapshot of the data collected and a good indication of the usefulness of the data. The question we have chosen to report on is Question 31, taken directly from the RSPQ – "I learn some things by rote, going over and over them until I know them by heart, even if I do not really understand the concept".

A total of 420 students across the two institutions responded to the survey; a 14% response rate. At least one response was received from each of the individual cohorts surveyed, with some cohorts such as the BE and MCOMP responding better than others. Our comparison of respondents (see Table 2 below) with the enrolled cohort (Table 1 above) to whom the survey was sent, leads us to believe that overall, we have a representative sample. There was, however, an especially low response rate from NZDE, BEngTech and DCOMP students which weakened the strength of conclusions that could be drawn from those survey responses. Therefore, when the project begins a concerted effort must be made to ensure that there is a significant response from all cohorts.

The following sections outline respondent demographics and discuss the reliability of this questionnaire.

Demographic profile

Table 2 and Figure 1 below, provide a snapshot of the demographic profile of students who participated in the survey. Table 2 compares the gender and enrolment of participants with the overall enrolled cohort of students from both institutions. All numbers are percentages.

Table 2: Demographics of respondents (res) against overall cohort (all)

	Gender				Enrolment			
	Male		Female		Domestic		International	
	All	Resp.	All	Resp.	All	Resp.	All	Resp.
Aus.	77	78	23	22	53	43.5	47	56
NZ	92	82	8.4	18	70	59	30	41

It is clear from Table 2 there is good representation of all groups in this survey. Figure 1 below identifies the activities respondents were engaged in during the two years immediately prior to this period of study.

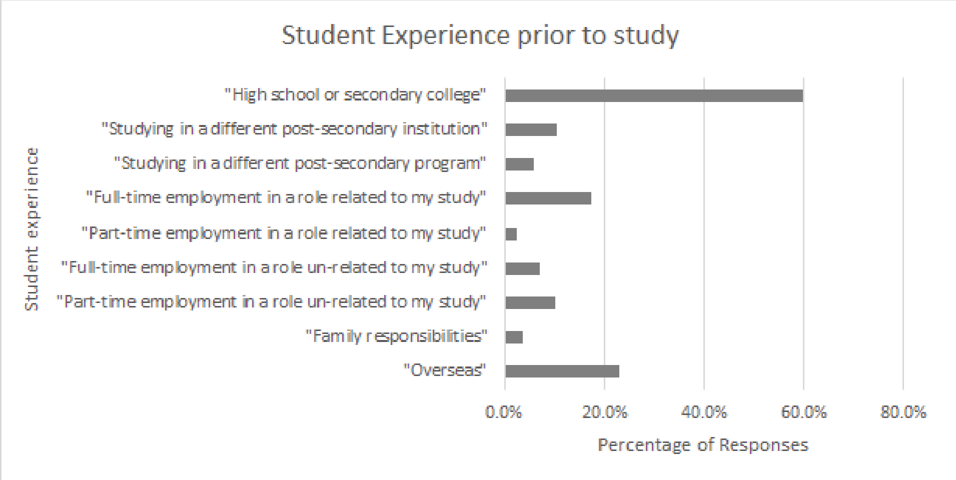

Figure 1: Respondents' experience 2 years prior to their current study NB. Students could select more than one option.

From the data, it is evident that most of the respondents are continuing their study at higher levels. It is also interesting to note that the number of respondents who identified as "overseas" is significantly less than the respondents enrolled as international students. This could be an indication that many international students may have been in the country longer than their current program of study and may be something we will investigate further in later stages of the project.

Reflection on Questionnaire Design

As mentioned above, we have chosen to report on the data collected for Question 31. This data is presented as a function of student experience two years prior to their current study in Figure 2 and then as a function of their level of study in Figure 3 below. As can be seen in Figures 2 and 3, when combined with demographic data the data collected through a single question of the survey indicates how a student's background and experience may affect their approach to study.

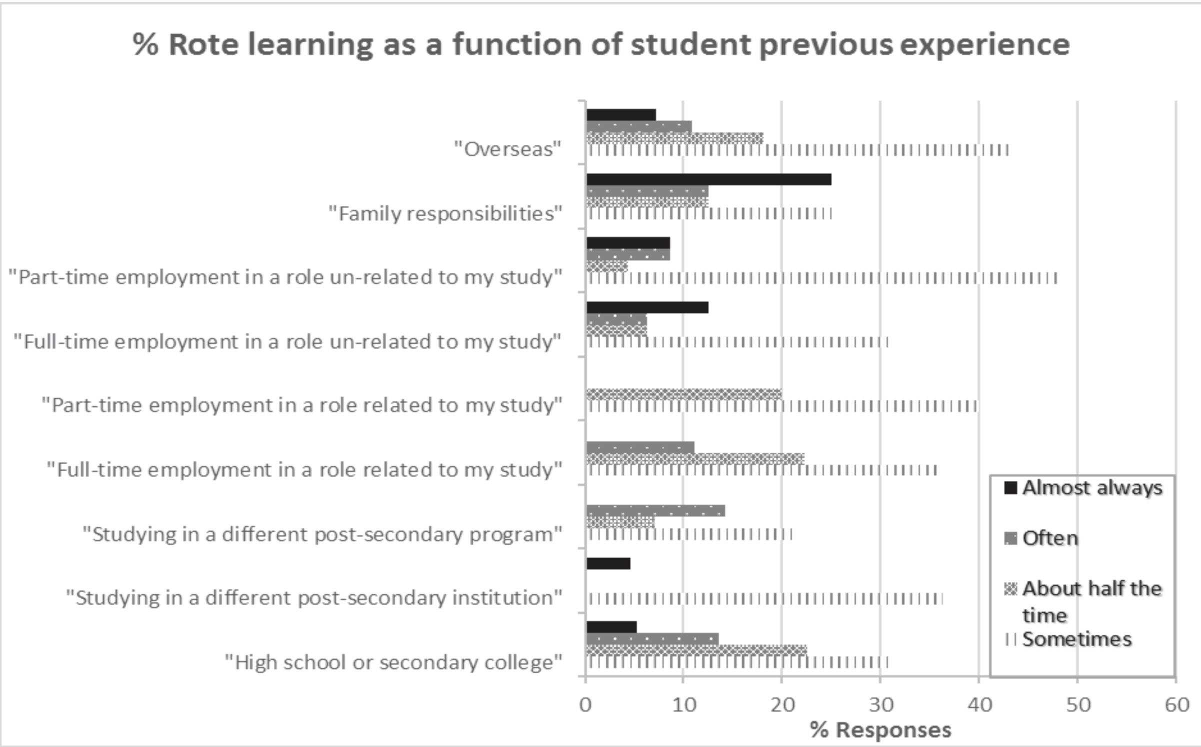

Figure 2: % Rote learning as a function of previous experience. NB. "Never" responses omitted.

The correlation between the students' level of study and their frequency of use of the rote-learning approach is shown in Figure 3. As the trend lines indicate, students studying in programs at levels eight and nine showed the strongest negative correlation with frequency of use of rote learning strategies, while the lower level programs showed a wider distribution of responses to the prompts.

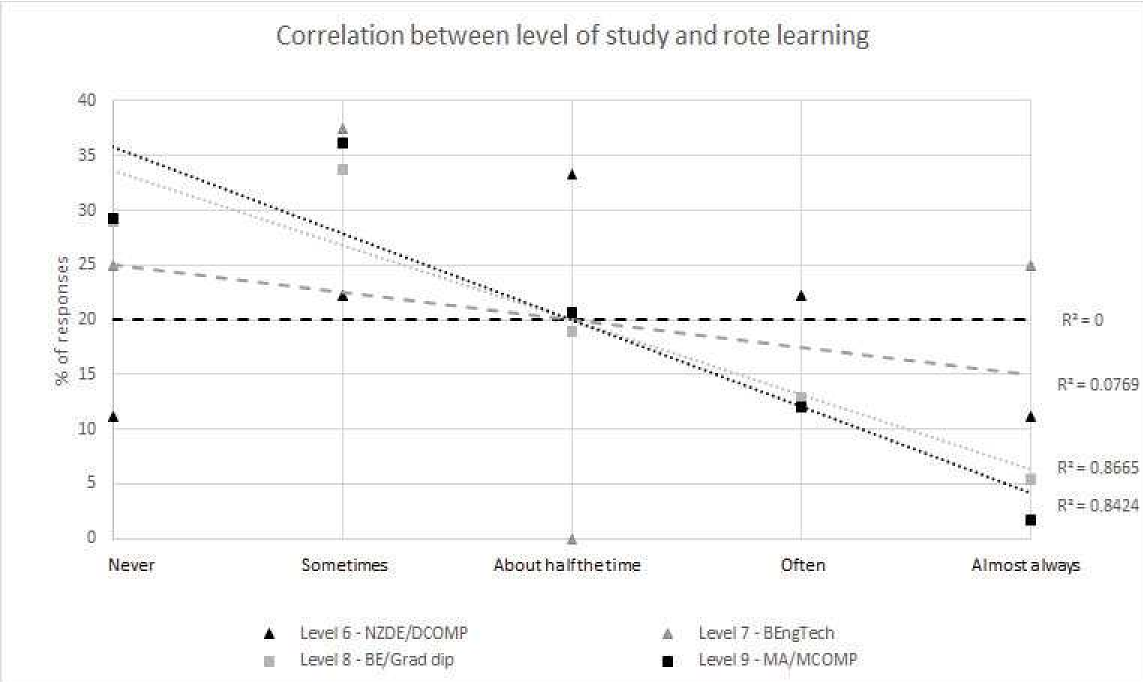

Figure 3: Correlation between level of study and rote learning.

The data suggests that students enrolled in higher-level programs are generally engaged in deeper learning strategies and have recognised the need for approaches other than rote learning for success as engineering / computing students. For students on the lower level papers the data presented in Figures 2 and 3 is so far inconclusive, and requires a greater detail of analysis.

The data collected and the brief analysis, some of which is presented above, gives the authors confidence in the ability of this survey tool to provide insights into relationships between students' approaches to learning and their demographics and background and experience. Detailed investigation will be undertaken in the following longitudinal study to identify correlations between approaches to learning and student demographics, background and experience for both engineering and computing students. As suggested by this basic analysis, detailed analysis is expected to identify topics for further investigation through focus group discussions.

Survey Design Issues

Survey respondents provided some unprompted feedback on the design of the questionnaire, identifying points where they had trouble providing a single answer on the Likert-scale. The researchers agreed that two questions from the RSPQ set needed clarification, as they combined two factors within one question. The first combined "I generally restrict my study to what is specifically set..." with "...as I think it is unnecessary to do anything extra". The second appears later in the questionnaire: "I find most new topics interesting..." paired with "...and often spend extra time trying to obtain more information about them".

Both questions appear to investigate the respondent's behaviour and motivation at the same time, when in fact different motivations could lead to the same behaviour. One student identified their time pressures as a motivator which sometimes lead to the behaviour of restricting study scope. Other respondents may well have had different motivations driving this behaviour, but the design of the questionnaire did not distinguish these.

This insight will be applied to update and refine the complete set of questions before the next phase of research begins in semester one, 2018. In this connection, it is important to note that the study, work, and social environment for post-secondary students has changed significantly in the years between 2001 and 2017. The use of subjective frequency-of-use headings for the Likert scale questions will also be reviewed, with possible addition of clarification for respondents regarding the frequency options. The authors are keen, however, while improving understandability of questions to maintain comparability against other studies which have used the RSPQ.

Additionally, it was pointed out by a student that when asking about gender, as well as female, male and rather not say, we need to include 'other' to allow those who identify as binary, trans-gender, gender diverse and LGBTQIA+ not to be forced to either mis-gender themselves or hide their gender.

Conclusion and Future Work

This pilot study of our approaches to learning questionnaire has been successful in evaluating the research design. The survey responses provided an excellent picture of student approaches to rote learning and the data appeared to show relationships with previous experience. Correlations and insights will be generated from in-depth analysis of the complete data set, which can be used to inform the design of teaching & learning activities and course and program curricula that will lead to better attainment of desired graduate attributes.

Despite the overall success of the pilot, there are a small number of issues that need to be addressed either prior to the longitudinal study or during it:

1. While respondents came from all groups within the cohort, the response rate was low for some programs. This issue will be largely overcome by accumulating data from the cohorts each semester the survey is run and by being proactive and ensuring that sufficient responses are collected from each of the individual program cohorts.
2. There were some issues with combined factors in the RSPQ questions which made it hard for students to respond accurately. Further analysis will identify which questions need modification to improve clarity of responses while maintaining comparability with other international studies which have used the RSPQ.
3. This study was unable to link responses to academic results due to ethics constraints therefore a further section, section (4) 'performance', will be added to the survey. Students will be asked to identify the two units of study (sometimes also called course or paper) in the immediately preceding semester for which they received their highest grade and their lowest grade. They will be asked to rate their approach to study, the final grade received and whether that grade was what they expected for each.

This work was an evaluation of the research design and the next step will be to begin collecting longitudinal data, apply Biggs et al.'s (2001) 50-point scoring system, evaluate and correlate the respondents' preferences for deep or shallow approaches to learning and to run focus groups to attempt to explore and understand areas of interest.

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[i] NZDE New Zealand Diploma in Engineering
DCOMP Diploma of Computing
BEngTech Bachelor of Engineering Technology in Engineering

BIT	Bachelor of Information Technology
BADA	Bachelor of Applied Data Analytics
BIT(Hons)	Bachelor of Information Technology (Hons)
BE	Bachelor of Engineering (Hons), Bachelor of Engineering Research & Development (Hons) (BE),
BSENG	Bachelor of Software Engineering (Hons
BAC	Bachelor of Advanced Computing (Hons), Bachelor of Advanced Computing Research and Development (Hons)
GCert/GDip	Graduate Certificate and Graduate Diploma of Applied Data Analytics, Graduate Diploma of Computing
MENG	Master of Engineering in Digital Systems & Telecommunications, in Mechatronics, in Photonics and in Renewable Energy
MCOMP	Master of Computing, Master of Computing (Advanced)
MADA	Master of Applied Data Analytics

Students' Social and Behavioural Factors Influencing the Use of Lecture Capture Technology and Learning in Engineering Education

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Abstract

Context

In spite of wider acceptance of lecture capture, questions remain about how the level of difficulties of courses affects the use of lecture capture. Most researches were conducted on the students of health science, arts, general science, or business courses. Little evidence was found for engineering education. Very few studies have focused on the students' social and behavioral factors (e.g. language, cognitive skills, attention level, past experiences) influencing the use of lecture capture and students' achievements in engineering education.

Purpose

This paper presents the influence of the students' attitudes, social and behavioural factors on using lecture capture technology and their learning in engineering courses.

Approach

Both qualitative and quantitative approaches were employed to analyze the perception of the students of various engineering courses in an Australian university.

Results

Results show that social and behavioural factors like mind concentration level, language, and past experience have an influence on using the lecture capture technology. A significant number of students having difficulties in attention to lecture class rely on lecture capture for further understanding. Variation of using lecture capture has also been observed among native and non-native English speaking students, and among the students with different level of past experience of using lecture capture. Despite availability of lecture capture, most students preferred attending lecture classes because of high mathematical contents and the experiments shown in the classroom. The study also gives notional indication that the lecture capture might have helped engineering students for improving their academic performance over the past few years.

Conclusions

Overall, the students' perception of lecture capture is highly positive in terms of improving learning and academic performance regardless of their social and behavioural characteristics. Further research should focus on how the teaching pedagogy for engineering education can be improved through enhancing lecture capture technologies to provide better service to the student with various social and behavioural differences.

Keywords

Lecture capture; Social and behavioral factors; Engineering education; Academic performance

Introduction

Learning and teaching in the universities are transforming towards the technology-based environment. To facilitate the students' learning in flexible, adaptive, iterative and user-friendly manner, lecture capture technologies are adopted by many universities, which make academic resources available to students through web-based media (McIntyre, 2011). Most of the lecture capture technologies use software that records the audio/ video, PowerPoint presentation and other digital materials shown in the computer provided by teachers in the classroom. These digital recordings are usually stored on a web server and are made available to the students via the university's web portal for viewing online or downloading the files (Owston, Lupshenyuk, and Wideman, 2011). Lecture capture technologies were initially evolved with the aim of supporting disadvantaged students who have difficulties in attending traditional lecture classes regularly (Harpp et al., 2004), as well as supporting online distance learning students (Woo, Gosper, McNeill, Preston, Green, and Phillips, 2008). The technology is now available to all students. Recent researches suggest that most students have used lecture capture as a supplement to the traditional face-to-face lecture (Davis, Connolly, and Linfield, 2009), primarily for revisiting complex concepts and having a clear understanding (Chiu and Lee, 2009). Few studies indicated the positive impact of lecture capture on students' grades (Owston et al., 2011; Kay, 2012), though those findings did not consider the other factors (e.g. social and behavioral patterns; academic development by the universities) that could also influence performance of the students (Ramsden and Entwistle, 1981). The impacts of lecture capture has been studied mainly in the field of health science, arts, general science, or business courses, with limited attention in specific courses like engineering courses where many hands-on experimental activities are involved in the classroom. This paper presents the influences of the students' social and behavioral factors on lecture capture use and students' learning approach in engineering courses, as well as impacts of lecture capture use on their academic performance and learning outcomes.

Methodology

This research employed both qualitative and quantitative approaches to collect and analyze the effects of students' social and behavioural factors (e.g. language, cognitive skills, attention level, past experiences) on lecture capture use in engineering education, and how the technology is impacting their learning outcomes. An extensive literature review was carried out followed by a survey of students with a structured questionnaire in an Australian university. This university has introduced lecture capture technology using Echo360 Personal Capture software in 2009, which records only a high-quality video of the computer screen (that showing PowerPoint presentation and other digital materials) and the lecturer's voice and uploads this to the university's learning portal. The students could access the video files online from any places; also, they could download them and view them on their personal computers multiple times. Students were asked to provide information on their attention levels, lecture capture use patterns, and their perceptions on different aspects of lecture capture. 120 students from various engineering disciplines (e.g. civil, mechanical, and electrical engineering) were randomly contacted for the survey, of which 85 students, who had past experience in lecture capture use, have responded to the questionnaire. Out of 85 students, 30 were non-native English speakers, and 92% attended face-to-face lectures. We assumed all the students had similar internet and computer facilities at home and at their university learning centers.

We relied on the students' self-reports about their lecture capture viewing patterns, instead of collecting digital records of online viewing or downloading files from the university portal, and without having further interaction with them. This could be a potential limitation of the research. However, several research studies have used a similar methodology, as students are believed to be accurate and credible reporters of their educational experiences (Owston et al., 2011).

Data analysis was performed using descriptive statistics and statistical tests (t-test, Post Hoc Tukey tests) to extract the influence of students' social and behavioural factors on the lecture capture use and effectiveness through cross-relational analysis. Further, 7-year historical records (2010 – 2016) of academic performance of the students in these five engineering courses were analyzed to assess the effect of lecture capture on their grades, with the intention of justifying the perceptions of the students surveyed.

Results

Student's attention level and attendance in lecture classes

First, the study analyzed the students' behavior in terms of their participation and attention or mind concentration level (MCL) in face-to-face classes throughout the day. 93% of the students stated they attended lecture classes regularly; however, around 50% of students reported they faced difficulties in concentrating in the class due to various reasons. The students were asked to measure their mind concentration levels at different times of the day (8 AM to 10 PM, during which most of the lectures are held) using a 10-point scale.

Most of the students reported that their MCL was very high in the morning around 10 AM - 12 PM, and it diminishes as the time passes (Figure 1). And, their concentration during the lecture class was not always the same, it depended on the time of day, and sometimes they could understand only part of the complex mathematical problems posed in their engineering courses. The students mentioned the major reasons for facing difficulties in concentrating in lectures as 'difficulties to understand/follow lecturers' (48%), 'class time is not suitable' (45%) and 'lecture content is not interesting' (40%). Difficulties to understand/follow lecturers was faced by the students due to lecturers giving either quick or brief explanation of the lecture contents, or students' inability to capture the ideas because of their limited background knowledge and weakness in English. Lecture contents of some engineering courses are mainly based on engineering principles and mathematics, which were reported as not interesting to some students so that they were distracted from the lectures. For a complete understanding, the students were dependent on recorded lecture capture, and additional consultation or study.

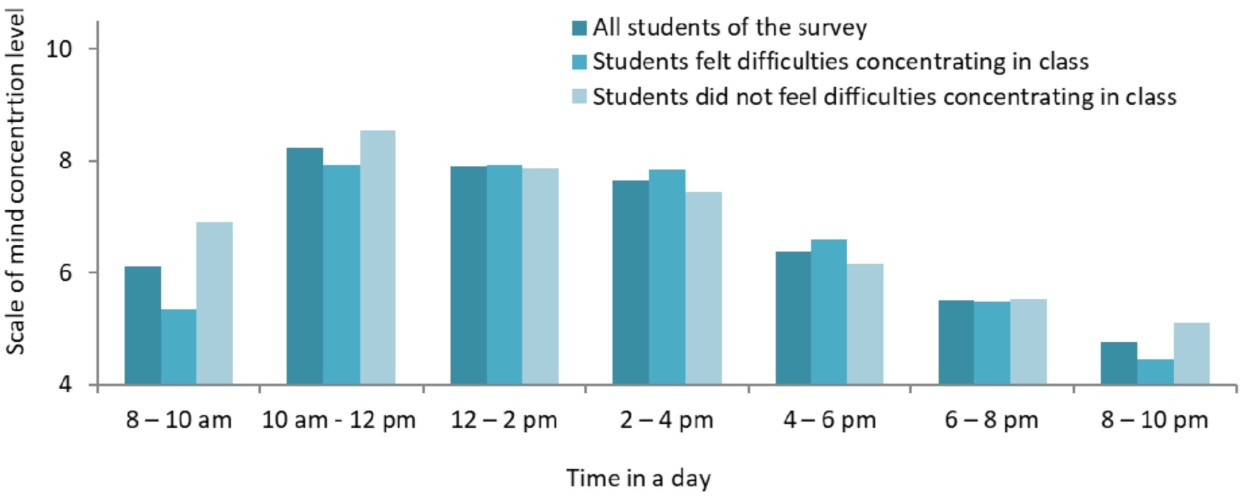

Figure 1: Student's mind concentration level in classroom

Effects of students' social and behavioral factors on using lecture capture

Lecture capture use pattern

Majority of the students (65%) had a long experience of using lecture capture, that is, more than two years. Almost all (93%) has attended face-to-face lectures besides using lecture capture. Most of them used recorded lecture captures regularly (40%) while some did only during the exam preparation (26%). Most students (70%) have used lecture capture more than one day a week with an increasing frequency before the exam periods during Weeks 5 to 7 (mid-semester exams) and Weeks 12 to 14 (final exams) throughout a semester. This trend explains the purpose of lecture capture for assisting the students for further understanding of lectures and preparation for exams.

The students apply various strategies for listening and watching the recorded lecture; most of them listened to the entire recording or certain parts of it multiple times (Figure 2). While listening, they have followed along with lecture notes (55%), as well as taken further notes (40%). The listening strategies of the students and their activities do not show any notable variation with how often they use lecture capture.

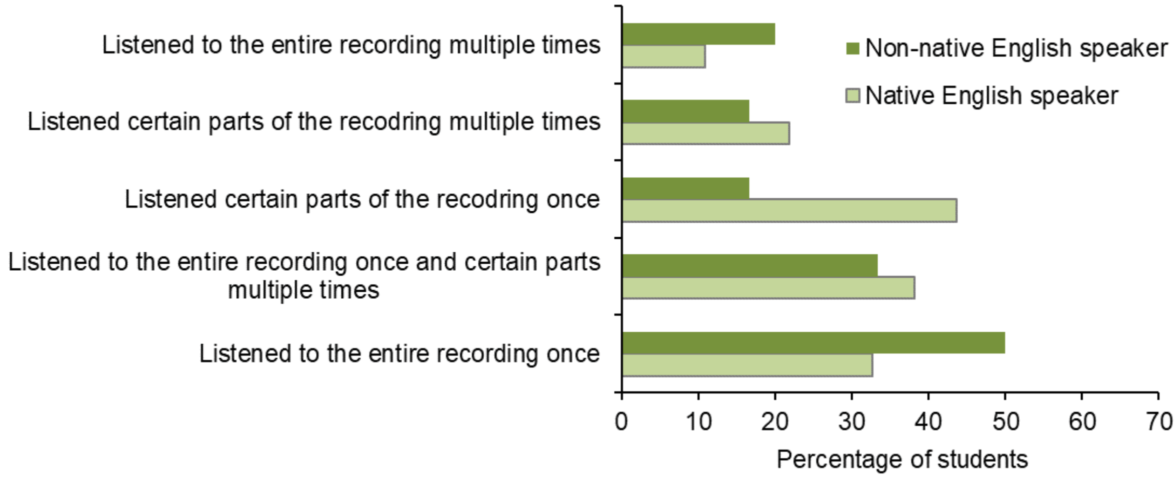

Figure 2: Students' strategies to listen to lecture capture

Influence of English speaking ability

The study has also investigated the effects of social factors, like English speaking ability of the students', on lecture capture use. In regard to the frequency of listening to lecture captures, there is no significant difference between the non-native and native English speakers ($t = 0.732$, $p = 0.46$), almost the same percentage of students (50%) from both groups listen to lecture captures regularly. Nevertheless, there is variation between groups in lecture capture listening strategies. Most of the non-native English speaking students listen to certain parts of the recording multiple times (50%), whereas most of the native English speakers (44%) listen to the entire recording once only (Figure 2). The activities during listening lecture capture (e.g. note taking) are similar for both groups.

Influence of past experience

The results showed that the percentage of students using lecture capture regularly increased with the students' past experience of using lecture capture (Figure 3). The students who had long past experience uses lecture capture regularly and during the exam preparation period compared to the less experienced students. However, the students' frequency of lecture capture use may decline slightly when they move on to courses at higher levels (Years 3 or 4) depending on the course structures. Further, the students' past experience did not show any influence in choosing lecture capture listening strategies.

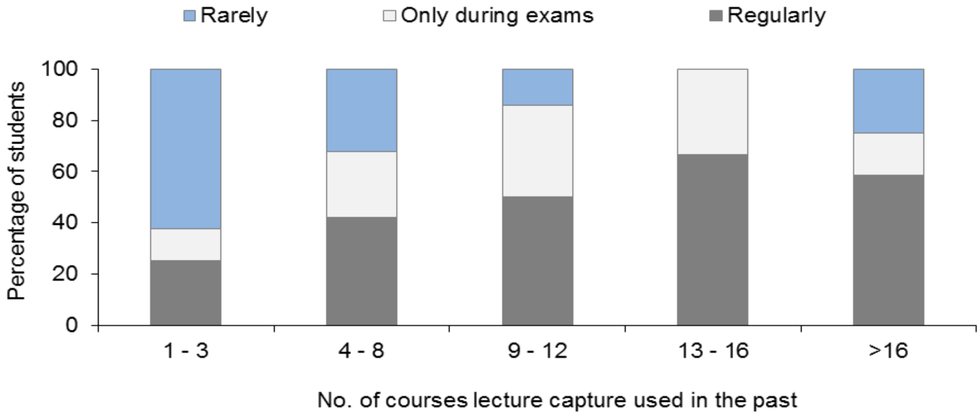

Figure 3: Using lecture capture by the students of different past experiences

Effects of lecture capture use on students' learning outcomes

The majority of students (90%) agree that lecture capture is an effective tool while studying or preparing for assignments and examinations, particularly when they miss classes (Table 1). They feel no stress if they skip a lecture class due to any reason. If they do not understand any important concept during the lecture, they can still use the lecture capture after class and listen to it multiple times until its concepts and contents are understood. Around 70% of students believe that lecture capture helps to raise their grades, as they gain a full understanding of the course materials.

Table 1: Students perception on lecture capture

Reasons for using Lecture Capture	Mean score of Level of agreement [a]
Lecture capture helps me catch up when I missed class.	4.5
Lecture capture is a convenient way to access course materials.	4.3
I could easily access and download the lecture recordings.	4.2
Lecture capture helps me prepare for assignments and exams.	4.1
Lecture capture clarified important concepts discussed in class.	3.9
I learned more in the class by using the lecture recordings than I would have if they had not been available.	3.9
Lecture capture helps to raise my grades	3.8
I could follow all parts of the classroom discussion on the lecture recordings, including student questions.	3.3

a Strongly Disagree (1), Disagree (2), are Neutral (3), Agree (4), or Strongly Agree (5)

With respect to the frequency of using lecture capture, the study has found a significant difference in the level of agreement on certain benefits of lecture capture. The students who used lecture capture regularly have a positive agreement about the benefits compared to those who used rarely. The Post Hoc Tukey test probabilities suggest that regular users agree that lecture capture helped for preparing assignments and exams, improved learning, and helped raise their grades compared to the rare users ($p<0.05$) (Table 2). However, the study has not found any significant differences in the levels of perception on the benefits of lecture capture between native and non-native English speaking students, or among the students having varying level of experience in lecture capture use in the past (for all items in Table 1, t = -1.55 to 1.57, p > 0.1).

Table 2: Post Hoc Tukey tests probabilities for various reasons for using lecture capture by students of varied level of viewing frequency

Variables	Comparing groups		*p*
Lecture capture helps me prepare for assignments and exams	Regularly	Only during exams	1.000
		Rarely	.023*
	Only during exams	Rarely	.042*
I learned more in the class by using the lecture recordings than I would have if they had not been available	Regularly	Only during exams	.972
		Rarely	.037*
	Only during exams	Rarely	.039*
Lecture capture helps to raise my grades	Regularly	Only during exams	.118
		Rarely	.022*
	Only during exams	Rarely	.819

*$P < 0.05$

Further, the study investigated the students' grades in five engineering courses over the period of 2010 to 2016 to examine the differences in students' achievement after the implementation of lecture capture in the university. While students' achievement could be linked to many factors, this analysis gives notional indication of the effect of lecture capture on such achievement. The analysis suggested that there was an increasing trend of passing (including achieving higher grades), after the implementation of lecture capture in 2010. Though the individual grades of the students surveyed have not been assessed, this finding can be easily correlated to the positive agreement of the students regarding improving grades due to lecture capture use (Table 1). About 40% students (mainly native English speakers, and having longer past experiences of lecture capture use) urged that most of their study needs can be fulfilled by lecture capture instead of attending lecture classes. Since class attendance is not compulsory, some students believe that they can cover the course study and assessments by using lecture capture only.

On the other hand, the students have expressed some negative effects of lecture capture on their learning. Especially, those students who miss the face-to-face lecture or laboratory classes complain of having difficulties in understanding the engineering courses containing extensive mathematics and drawings that are usually explained on the whiteboard or with hands-on experiments, but not recorded in lecture capture.

Discussion and conclusions

This research reveals the students' behavior of participation in lecture classes and what difficulties they face that lead to deterioration of mind concentration level in the class. The mind concentration level of the students shows a logical trend throughout the day. Other major difficulties in retaining attention are reported as lying with the lecture contents, and how the lecturers deliver it (Wilson and Korn, 2007). The students prefer using lecture capture to cover the lectures which they could not follow properly. This attitude might have an effect on attention in the class. However, lecture capture can only act as a means for the retention of information, not for illustrating further information (Savoy et al., 2009) outside of lectures.

The study shows that most students use lecture capture regularly for an in-depth understanding of lecture contents, particularly during exam periods. Teachers are often worried about having low student attendance in the class because of availability of lecture capture (Vajoczki, Watt, Marquis, and Holshausen, 2010). However, as our results show, despite availability of lecture capture, most engineering students' (93%) attended the lecture classes, irrespective of their language skills and past experience of using lecture capture. This attitude could be related to the nature of the engineering course contents which need hands-on examples or mathematical derivations on the whiteboard that are not accessible by the lecture capture.

The strategies and activities taken by the students for using lecture capture show typical patterns which have also been observed in other universities (Copley, 2007; Kay, 2012). Students having a non-English speaking background tend to use lecture capture for further understanding and note taking (Leadbeater, Shuttleworth, Couperthwaite, and Nightingale, 2013). We found this purpose to be shared by non-native English speakers in this study, although there was no statistically significant difference between native and non-native English speakers in terms of their opinions in other areas of the survey.

Further, while looking into social factors like past experience with lecture capture, the study shows that students with longer past experience of it tend to use it more regularly than others, however, this was generally true for students in their middle of the undergraduate course (2nd or 3rd year). Final year students may need to use lecture capture less frequently as they have courses like project work and a thesis. The course contents and the teaching pedagogy of the lecturer may have a great influence on how students use the recordings of lectures (Bassili, 2008).

This research also suggests a very positive perception of engineering students for lecture capture, in that they believe it improves their learning and academic performance, which is a similar finding to those of studies conducted in different academic courses (e.g. health science, arts) (Leadbeater et al., 2013). Regardless of differences in social factors (English language skills and past experience), most students agree on the positive impact of lecture capture. Gradual improvement in the students' overall academic achievement in a few engineering courses over the past few years also justifies the students' positive perceptions. Opportunities for taking extensive notes while viewing the lecture recordings repeatedly could have an influence on improving academic performance (Bassili and Joordens, 2008).

Students have complained of the incompleteness of lecture capture in that it does not include the video of notes displayed on the whiteboard, which cause difficulties for understanding complex engineering concepts. This problem is due to technological constraints and also faced by other universities (Read, 2005). Improving video recording facilities with additional resources, often called – 'rich lecture capture' can resolve the issue (Kay, 2012; Pale et al., 2014). For some engineering courses, however, hands-on experiments in the class are included, thus it will not be possible to record all such lectures completely. However, rich lecture capture could be possible for literature-based courses like arts and business, as they require concepts to be explained through theoretical lectures only (Morris, 2010).

Further detail research should be carried out focusing improvement of teaching pedagogy for engineering education with enhanced lecture capture technologies for ensuring better service to the students with various social and behavioural differences including psychological, economic, and access to information technology.

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Intensive Mode Teaching for the delivery of engineering content to students at a Chinese university.

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SESSION Integration of theory and practice in the learning and teaching process'

CONTEXT Interactive Intensive Mode Teaching (IMT) techniques were used to deliver an engineering design and project management unit at a Chinese university. A proportion of Chinese students studying this unit transferred to the University of Tasmania to complete a Bachelor of Engineering with Honours degree in a further two years (2+2 Program). The unit was delivered over a period of six weeks to large classes (75 and 115 students). At the same time students intending to transfer to UTAS undertook an English language academic skills unit. Both units were facilitated by the introduction of an on-line learning management system (Cloudcampus).

PURPOSE This study examines the effectiveness of the interactive IMT technique for the delivery of KNJ211 *Engineering Design and Project Management* by comparison with the traditional, didactic style of teaching employed by the same teacher in the previous year; the synergy between the engineering unit and an English language unit, delivered by the second author at the same time, is also explored.

APPROACH The effectiveness of interactive IMT delivery was evaluated through students' performances in aligned assessment tasks comprising a 5-minute video report on design studio group-work, in-class tests of content knowledge and an individual task. Students' engagement with IMT is examined through the lens of their use of Cloudcampus.

RESULTS The students' overall and in-class test results were significantly different from those of the previous year when the unit was delivered by the teacher-centred didactic method. A factor that may have contributed to this outcome is students' unfamiliarity with accessing the on-line content.

CONCLUSIONS Students' technical English language skills present a challenge to effective delivery of engineering content. Some IMT techniques proved to be effective.

KEYWORDS

Intensive Mode Teaching
China
Engineering

Introduction

Academics from the University of Tasmania (UTAS) deliver first, second, third and fourth year engineering subjects to students at Chinese universities. Some of these students choose to graduate with a Bachelor of Engineering with Honours degree by completing their final two years at UTAS (2+2 Program). The interactive Intensive Mode Teaching (IMT) technique recommended by Male et al. (2016), developed specifically for the delivery of engineering among other content, was used to deliver a second year engineering unit KNJ211 *Engineering Design and Project Management* to large classes (approximately 100 students) at a Chinese university over a period of six weeks in May-June 2017. At the same time students intending to transfer to UTAS undertook an English language academic skills unit. Both units were facilitated by the introduction of an on-line learning management system (Cloudcampus).

This study examines the effectiveness of the interactive IMT technique and the assessment tasks used for the delivery of KNJ211 by comparison with the traditional, didactic style of teaching employed by the same teacher (first author) in the 2016. The synergy between the engineering unit and the English language unit (*Academic Skills Program*), delivered in the same six week period by the second author is also explored.

KNJ211 *Engineering Design and Project Management* was delivered (by the first author) to two cohorts of students studying Electrical Engineering and Automation and Communications Engineering over a six-week period in 2017. There were approximately 100 students in each cohort. The timetable for each cohort was 4 hours in a lecture room and 8 hours in a design studio each week. The teaching load for the UTAS teacher was 24 hours contact each week. Chinese university lecturers (third and fourth authors) were present in the class-room and design studio most of the time. All delivery was in the English language except for announcements (in the Chinese language) by the Chinese lecturers.

Literature Review

The challenge of teaching in China

Globalization has encouraged the emergence of large economies due to the fluid mobility of people, thus changing cultural patterns and diversity in higher education. According to the International Consultants for Education and Fairs, Australia hosted the greatest number of international students at higher education which provided (AUS) $1 billion in 2014 (ICEF Monitor, 2015). For the past 20 years, full-fee paying overseas students have contributed a significant component of Australian universities' income (Dunn & Wallace, 2006; Wang et al., 2015). A considerable amount of research has been conducted looking at both undergraduate international students (Birrell, 2006; Burns, 1991; Malau-Aduli, 2011; Ramburuth & McCormick, 2001; Wong, 2004) and postgraduate international students (Wang & Shan, 2006), when transitioning to Australian universities especially from China.

Stereotypically, Chinese student learning styles are considered to be surface learning approaches where the student is a passive participant (Ramburuth & McCormick, 2001; Wong, 2004). But they adopt the methodology of learning by repeating and memorizing content for understanding. During the process they have the opportunity to reflect on troublesome content and devise methods to promote better understanding of instruction. These may include seeking assistance from the more knowledgeable other (Vygotsky, 1978), task analyzing complex concepts, and investigating vocabulary words to clarify the meaning of content. Thus they develop deep approaches in learning. The reflective nature of Chinese learners in developing a deeper understanding than what may be apparent from classroom participation is also documented (Wang & Shan, 2006).

The Chinese education system is designed to facilitate large classes. There are no disciplinary problems because they have been taught from young to respect their teachers since the Confucius era (Guo & Pungur, 2008). Content is delivered in a manner that may appear to outsiders to be rote learning. But there are some misconceptions concerning the learning and study practices of Chinese students in Australia (Kember, 2000). Whereas Australian universities adopt the independent learner model, Chinese universities typically follow more of a parent-child relationship between the teacher and student (Wang & Shan, 2006). There is a strong peer support as well as access to teachers outside the classroom (On, 1996).

Doe, Jaikaran-Doe, Lyden and Wang (2016) surveyed newly-arrived civil engineering students in their first semester in the third year of a civil engineering degree at the University of Tasmania. The survey probed the students' experience of learning and teaching experience in China, in particular in the classes delivered in China by Australian academics. That study identified the different learning and teaching styles of the Australian teachers as being of most concern to students while they are still in China; but after coming to Australia it is their language that is of most concern - particularly understanding technical terms. In another study Ryan (2005) found that students encounter culture shock and academic shock at the beginning of their study in Australia. The delivery of engineering content using interactive Intensive Mode Teaching has the potential to assist these students with their transition to UTAS

Methodology

The effectiveness of interactive IMT delivery was evaluated through students' performance in the following: summative assessment tasks aligned to the unit's Intended Learning Outcomes (ILOs); group-work video; fortnightly in class tests; and an individual assignment task (see Table 1). Participants were students enrolled in the second year of electrical power and communications engineering degrees at the Chinese university. Students' engagement with IMT was examined through the lens of the use of the on-line learning management system (Cloudcampus). Independent samples *t*-tests (with test for Normality) were employed to examine the significance of differences between students' results in 2016 and 2017. The level of student engagement in 2017 was the proportion of students who accessed the on-line student management system during the period the unit was delivered. There is no comparable data for 2016 prior to the introduction of Cloudcampus.

Didactic learning and teaching in 2016 (teacher-centred)

The term didactic delivery is often used to describe the traditional learning and teaching practice in China. In 2016, prior to the introduction of an on-line learning management system (Cloudcampus) at the Chinese university, the unit KNE211 *Engineering Design and Project Management* was delivered (by the first author, assisted by the third and fourth authors) in the traditional teacher-centred style with the teacher delivering content knowledge from a raised dais in front of a blackboard to approximately 100 students sitting in rows of fixed seating. The available resources for teachers included a stationary computer, document camera, video projector, and a sound system. Slides, videos and the emphasis of important points by writing (with chalk) on a blackboard were the major delivery tools. Engagement with students was limited to those students who chose to sit in the front rows, and exhibited the best English.

Intensive Mode Teaching in 2017 (student-centred)

The term 'student-centred learning' refers to a wide range of learning styles focussing on the needs and interests of students. Interactive Intensive Mode Teaching (IMT) techniques have been developed and successfully deployed in Australian universities (Male et al., 2016). The following IMT techniques were employed in the delivery of KNJ211 *Engineering Design and Project Management* at the Chinese university in May/June 2017:

- All lecture material was uploaded onto Cloudcampus before the start of teaching.
- In-class sessions were limited to four hours/week to maximise time in the design

studio.

- Content in the uploaded notes was **not** repeated in class (for example the explanation and function of the Raspberry Pi General Purpose Input/Output port, also programming in Python and the EV3 LEGO robot languages).
- An on-line formative assessment (Quizizz.com) preceded each fortnightly summative test, as was found valuable in a unit on critical theories of technological development and an intensive accounting unit delivered elsewhere (Crispin et al., 2016).
- Student engagement was encouraged both in-class and in the design studio through group competition.
- Time in-class was allowed for groups to discuss threshold concepts and report verbally or by writing on the blackboard.

Intended Learning Outcomes

The following statement on ILOs was approved by the UTAS School of Engineering and ICT's Learning and Teaching Committee and included in the KNJ211 *Engineering Design and Project Management* Unit Outline:

On completion of this unit, students should be able to:

1. Demonstrate an understanding of the fundamentals of Engineering Design, Project Management, Engineering Ethics and Sustainability,
2. Develop and evaluate conceptual designs to address the problem specifications,
3. Function as an effective team member using simple project management tools to build and test a prototype design,
4. Critically reflect on your and others contributions to the team and the execution of the project.

Assessment tasks

Assessment tasks for KNJ211 *Engineering Design and Project Management* delivered in 2017 comprised a group video report on the design-and-build component together with fortnightly in-class tests and a one-page, handwritten diagram (with explanation) of one of the micro-processor based circuits built and tested in the design studio.

Table 1 details the assessment tasks and their alignment to the unit's ILOs and Engineers Australia (EA) Elements of Competency for Stage 1 Professional Engineers (Engineers Australia, 2017).

Table 1: Alignment and weighting of Assessment Tasks, ILOs and EA competencies

Component	Weight	Due Date	Addresses ILOs	Addresses EA competencies
1. In class tests (Individual)	36%	Fridays weeks 2,4,6 in class	1.	1.3, 3.1
2. Circuit diagram (Individual)	14%	End of Week 6	2.	1.4, 2.1, 3.3
3. Project (Team)	50%	End of week 6	3. and 4.	2.4, 3.5, 3.6

Engineers Australian Stage 1 Competencies

Graduates satisfying the Stage 1 competencies for professional engineers is part of the requirement for accreditation of engineering schools at Australian universities (anon, 2017). The competencies that the unit KNJ211 claims to deliver are listed below:

1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline.

1.4 Discernment of knowledge development and research directions within the engineering discipline.

2.1 Application of established engineering methods to complex engineering problem solving. Vital aspects of an engineer's skill encompass design, innovation and project management. It is essential that an engineer can work within a framework of professional standards and yet have the innovative skills to produce creative design solutions. Students submit two team-work assignments.

2.4 Application of systematic approaches to the conduct and management of engineering projects. Students develop an understanding of the fundamental concepts of engineering design, through studying the design of everyday artefacts as well as professional design practices. Students are introduced to contemporary concepts of innovation and project management within a competitive environment.

3.1 Ethical conduct and professional accountability. Students are introduced to the Engineers Australia code of Ethics.

3.3 Creative, innovative and pro-active demeanour. Students apply creative approaches in a design situation

3.5 Orderly management of self, and professional conduct. Students have multiple tasks to prepare and report on a strict deadline with penalties for late submission. This necessitates prioritization given the requirements of other units.

On-line learning management system

The Chinese university introduced an on-line learning management system (Cloudcampus) in time for the delivery of the KNJ211 Engineering Design and Project Management unit in May/June 2017. The Unit Outline and all lecture notes were uploaded two weeks before the start of teaching. Over each weekend the teacher uploaded the content to be delivered the following week with sections highlighted to show the threshold concepts which were to be discussed during the in-class sessions. In-class, the lecturer projected the content as a MS Word document (rather than PDF or PowerPoint) so other threshold concepts could be highlighted at the time if needed.

Results

Summative assessments

Table 2 shows a comparison of results for the summative assessments in KNJ211 *Design and Project Management* (N=186) delivered in 2017 (using the IMT techniques) with the results of a similar cohorts (N=194) who took the unit KNE211 *Engineering Design and Project Management* in 2016, delivered by the same teacher using teacher-centred, didactic teaching methods.

An independent-samples t-test was conducted to analyse the students' results.

Cohen's d was computed to identify and verify the magnitude of the differences between the means of the 2016 and 2017 results.

The overall result for the 2016 students (M=80.2%, SD=9.21%) was significantly better (p<0.0001, t=-4.37) than the results achieved in 2017 using the interactive IMT techniques. *Cohen's d* was 0.90 indicating a "large effect size". This result was unexpected.

Considering only the individual test results, which could be seen as a measure of the effectiveness of the interactive IMT delivery of content, the 2016 class (*M*=85.9%, *SD*=12.3%) performed significantly better ($p<0.0001$) than the 2017 class (*M*=77.8%, *SD*=12.8%). With a *Cohen's d* of 0.645 this can also be considered as a "large effect size". The reasons for these unexpected results are explored in the Discussions section below.

The Design Project (*M*=70.4%, *SD*=10.4%) component in 2016 carried a 36% weight in the students' overall result and included a competition component in addition to the group video report. A design group's competition rank in the "LEGO Robot Rugby" competition and the "Chopsticks Tower" competition contributed to the group's Design Project mark. In 2017 the Design Project (*M*=75.7%, *SD*=8.46%) was weighted as 50% of the students' overall result. The change from 2016 reflected the introduction in 2017 of a Raspberry Pi based microcomputer design project in place of the "Chopsticks Tower" competition. There was no competition component in the 2017 Design Project assessment. By comparison the 2017 Design Project scored significantly higher ($p<0.0001$) than the 2016 Project. Cohen's d = 0.56 indicates a "medium effect size" for this result.

The relatively low result (*M*=50.0%, *SD*=29%) for the individual, hand-drawn circuit diagram is a contributing factor to the low overall result in 2017. By contrast the equivalent individual assessment component in 2015 (a portfolio) achieved a uniformly high result (*M*=69.3%, *SD*=3.5%). The hand-drawn circuit diagram was introduced in 2017 to encourage individuality.

Table 2: Components of students' overall performance.

Assessment Task	2016		2017	
	Mean (%)	Standard Deviation (%)	Mean (%)	Standard Deviation (%)
In-class tests	85.9	12.8	77.8	12.8
Design Project group video report	70.4	10.4	75.7	8.5
Circuit diagram	n.a.	n.a.	50.0	29
Overall result	80.2	9.2	71.7	9.6

Discussion

Student-centred versus teacher-centred learning and teaching

Segers & Dochy (2010) comment that whereas teachers and students are moving towards new learning environments and modes of assessment acceptance is not a simple process, particularly for problem-based learning. In a study involving non-Chinese teachers of English at a Chinese University, Wang (2011) found *'Chinese students expect that the teachers' role is to transmit information rather than engage students in dialogue and challenging students to think'.*

Feedback from one student on the trial conducted (by the first author) of IMT techniques in a final year engineering unit at UTAS in March 2017 suggested that the expectation of students was for a lecturer to “teach” them. (P.Doe personal communication 30 June 2017). The focus of student-centred learning is for the students to “learn” rather than be taught. If a final year engineering student in Australia wants to be "taught" it could be that the acceptance of IMT in China would be problematical considering Chinese students history of didactic learning. It may also be that interactive Intensive Mode Teaching techniques have only recently been introduced in the delivery of engineering units at UTAS and elsewhere. Students develop an expectation based on their prior years of study and when something different is introduced they are resistant.

Technical English fluency

Teaching and learning in the design class was constrained by students' lack of technical English fluency. Most students did not know the English word for "screwdriver". A student in the design studio looked blankly when the teacher offered to "fix" a problem with a motor-driver. Other students chose to download Chinese language versions of software making instruction by the UTAS teacher difficult. Lack of English fluency has been shown to be the major factor in Chinese students' poor performance in their first semester in Australia (Doe et al., 2017). It is possible that students' ability to read and understand the content uploaded in English to the on-line learning management facility is also a limiting factor in the effectiveness of interactive IMT in China.

On-line learning management system

The interactive IMT delivery is critically dependent on students accessing course material uploaded in advance to the on-line learning management system (Cloudcampus). This system was introduced to the Chinese university towards the end of 2016 with the result that students had not developed a culture of accessing and interacting with Cloudcampus. Even though both the engineering content and the English language teachers stressed the importance of regularly reading postings on Cloudcampus only 45% of the students enrolled in KNJ211 *Engineering Design and Project Management* accessed the information in Cloudcampus. However it should be noted that Chinese students enjoy strong peer support through living together on campus. Content downloaded from Cloudcampus could have been shared.

Synergy with English language program

During the 2017 delivery of the content KNJ211 *Engineering Design and Project Management* there were instances where synergies in the form of students' use of vocabulary from their *Academic Skills Program* occurred. As an example - in the delivery of content on Engineering Ethics the teacher identified 'bias' as a threshold concept. After allowing a few minutes for the design class groups (8 students in each group) to discuss the concept, the teacher handed the chalk to one of the students who wrote an example of 'bias' on the blackboard. The student wrote: '"An example of bias could occur at a job interview when the applicant was not appointed on the basis of race". The teacher was surprised by the vocabulary until it was pointed out that students had participated in mock interviews in their *Academic Skills Program* class by the second author.

Formative assessments

A mobile phone or personal computer based quiz, *Quizizz* (www.quizizz.com) was used as a formative assessment in both the students' engineering and Academic Skills program language classes. A *Quizizz* test was set as homework in KNJ211 two days before each of the in-class, paper-based, fortnightly (summative) tests. Likewise *Quizizz* tests were used in the *Academic Skills Program* as a formative test of students' technical vocabulary. Access details for the *Quizizz* website (join.quizizz.com) were displayed in the design classes. Because *Quizizz* is voluntary and anonymous it is not possible to assess its effectiveness as a teaching and learning tool. However the response rate for the three *Quizzes* tests in KNJ211 (222, 145, 113 attempts respectively) is some indication of their effectiveness in encouraging student engagement. Several students questioned the teacher on items in the *Quizizz* tests.

In September this year the principal author delivered a different unit KNX240 Reliability Engineering at another Chinese university. Based on the experience with delivering

KNJ211 earlier in the year using *Quizizz* the quiz facility in Cloudcampus was used for a formative assessment at the end of week 1. This had the desired effect: all enrolled students logged into Cloudcampus in order to participate in this assessment.

Summative assessments

In-class tests

Individual, written, tests (worth 36% of the final mark) were conducted in-class on the second, fourth, and the last Friday of the six-week teaching period. In KNJ211 delivered in 2017 the first two tests comprised 12 statements written in simple English requiring a TRUE/FALSE response. For example: 'Crashing a project means that it has failed' (FALSE). The final test was multiple choice modelled on the Quizizz formative tests. All in-class tests were designed to assess students' understanding of content rather than their proficiency with writing. Tests were not conducted with the same attention to individuality as with formal examinations in Australia. In one class there were 113 students sitting beside one another in the class-room. It was evident from marking that some students had compared answers despite the attention of two invigilators.

One-page hand written circuit diagram

This assessment was introduced in 2017 to assess a students' contribution to the design-studio group work. The handwritten requirement was intended to prevent photocopying or copy/paste of other students' submissions as had occurred with a portfolio assessment in the same unit in 2015. This strategy was only partly successful; students were observed copying others' reports in the hour leading up to the deadline. The low mark for this task (M=50.0%, SD=29%) may reflect students' expectations that their video project mark together with their test aggregate mark would be sufficient for a pass grade in this unit. Only two of the students presented drafts for the teacher to review before submission despite repeated invitations.

Group video reports

Video reports have been used for summative assessment in *Engineering Design and Project Management* units at the Chinese University every year since 2014 also in 2015 at UTAS when the same teacher (PD) delivered the same unit (but with a different unit code). The incentive for this form of assessment was a workshop on *digiExplanations* conducted by Hoban (2013) from the University of Wollongong. This form of assessment is particularly suited to the delivery of a design and project management unit in China. It minimises the emphasis on written English skills by students whose English is a second language. Producing a high-standard 5 minute video within a three to six week time frame is a project in itself, given the students had no previous experience in video production.

Recently there has been discussion within the School of Engineering and ICT at UTAS on the merits of a group video as a major (50%) component of the assessment in this and other units on-shore and off-shore. On-shore, some students have expressed their dislike of group presentations (not just video reports) as they feel that members of the group either can-not or do-not contribute with the result that the individual's mark does not reflect their ability or effort. This also applies in some extent to group laboratory reports on-shore.

The ability of a group video report to assess Intended learning outcome in KNJ211, namely "Critically reflect on your and others contributions to the team and the execution of the project", was challenged by a UTAS L&T committee member. In defence, the group video report the assessment rubric (for a High Distinction mark) requires that "The video describes the roles and contributions of all the team members". However at the other (Pass mark) end of the scale the requirement is only "The video contains only the names of the team members".

Conclusions

Notwithstanding the authors' enthusiasm and initiative in embracing student-centred learning and interactive IMT techniques, the effectiveness of delivery of the **KNJ211** *Engineering Design and Project Management* at the Chinese university in 2017 (as measured by students' results) was disappointing.

This experience further confirms the authors' observations that Students' technical English language skills present a challenge to effective delivery of engineering content.

However some IMT techniques proved to be effective as evidenced by students' in-class participation in the discussion of threshold concepts.

The University of Tasmania is in the process of revising the curriculum for its Bachelor of Engineering with Honours Degree. The revised curriculum includes a significant component of experiential, project based learning and design project across all specialisations. If student-centred learning and teaching is to be embraced in the new curriculum it is vital to explore further the reasons for the disappointing results from this introduction of interactive Intensive Mode Teaching in China.

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DEVELOPING A MANAGEMENT SYSTEM FOR ENGINEERING EDUCATION (MASEE)

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Increasing the authenticity of the engineering curriculum through engagement with industry has been recognised as essential to aid transitions from education. Exposing student engineers to, and requiring studies to be undertaken within, an industry adapted Management System for Engineering Education (MaSEE) is proposed as a means of increasing this authenticity. The concept has been developing over the past five years to address an identified gap in the curriculum with regards quality management processes. Quality management processes provide the opportunity for socio-technical considerations to be integrated into the design process and reflect how engineers operate in practice.

PURPOSE This paper furthers the development of MaSEE. It explores perceptions from industry on critical processes to embed into the curriculum, outlines trials of the processes and resources that will be available to engineering educators.

APPROACH This project is funded by the Australian Government Department of Education and Training and uses an action research approach to develop, trial and refine six teaching resources that will enable adapted industry management system processes to be used as learning and teaching tools. Industry participants have provided input into identification of the processes and will also be given the opportunity to review the developed resources for authenticity.

RESULTS This project is the extension of an exemplar trial of a design verification peer review process. The trial demonstrated that students were able to appreciate the adapted industry process, and its use enabled an increased understanding of technical content. Industry participants have now validated which other processes should be adapted for use. These include design review, document control and project planning.

CONCLUSIONS This paper identifies the value of student engineers using industry adapted management system processes within their studies. It also outlines further work to be undertaken on the project.

KEYWORDS

Curriculum, industry, employability.

Introduction

The approach to work adopted by professional engineers is different to the engineering student's general approach to their learning of the fundamental technical skills required to practice professionally. The approach used by professional engineers is informed by management system frameworks which provide consistent protocols and processes for use. The ability to appreciate and work within these protocols provides transferable skills that are directly related to the employability of a graduate, and engineers more broadly. These skills are recognised competencies, which are well defined for engineering programs.

This paper reviews the professional competencies and transferable skills required by graduate engineers and proposes the introduction of adapted industry management system processes as a means of development.

Professional competencies

Over the past one to two decades there has been an increasing emphasis on defining what competencies are required by engineering graduates, and university graduates more broadly. From an engineering perspective, the first competency Standard was introduced in 1993 and each subsequent revision (1998, 2003, 2006, 2011 and 2013) has shaped our understanding of the learning outcomes to be considered, developed and assessed within progressive engineering curricula. The revisions made to the Standards between 2006 and 2011 were significant and informed by national Australian Learning and Teaching Council (ALTC) funded projects defining the future of engineering education, including: the landmark Addressing the Supply and Quality of Engineers for the New Century report (King, 2008); and the Threshold Learning Outcomes (TLOs) developed by the ALTC Discipline Scholars in Engineering and ICT (Wright, Hadgraft, & Cameron 2011). A key feature of the 2011 revision to the Standard was the inclusion of a specific Indicators of Attainment for each competency with more depth than had previously been seen. These indicators are provided for guidance, but explicitly characterise professional engineering practice.

A challenge for engineering educators relates to the complexity of devising curricula to develop these non-technical competencies when, traditionally, the curriculum was designed to develop the technical/analytical knowledge base that provides the foundation for engineering practice. This is particularly the case at present as the programs go through re-accreditation using the revised Standards. If more time is dedicated to the development of non-technical competencies, which core technical knowledge content is removed? Or, should educators attempt to just squeeze the content and fit everything in? The answers to these questions are not clear and necessitate the need for further investigation of pedagogical approaches that appropriately blend academic and practical learning experiences, and which see students prepared for work with the right mix of practical and theoretical/academic skills.

In many engineering programs non-technical competencies are developed in 'professional practice', 'management' or 'communication' units of study, which are bolted onto the core discipline knowledge, and often perceived by students to be less important than the development of technical skills (King, 2008). Chanda and Nicholls (2006) suggest that there is some merit in this. However, to aid the development of the skills there is also merit in curriculum design that incorporates a mix of bolted on, embedded and integrated approaches. An embedded approach incorporates non-technical competencies into curricula but there is no direct reference or assessment of their development. An integrated approach seeks to develop the competencies in parallel with technical content. An example is Project Based Learning (PBL), which has been shown to be appropriate for engineering (Mills & Treagust, 2003; Maier, 2008; Schaller & Hadgraft, 2013). The success of PBL activities can be related to the selection and authenticity of the project to be undertaken, with industry inspired projects being preferred.

The use of industry inspired projects, and greater engagement with industry more broadly, is strongly advocated by Engineers Australia, was a key recommendation of King (2008) and has been explored by the Australian Government Office for Learning and Teaching (OLT) commissioned projects (Jollands, 2015). The Best Practice Guidelines for Effective Industry Engagement in Australian Engineering Degrees is another recent publication that was an outcome of an Australian Council of Engineering Deans (ACED) project (Male & King, 2014). The guidelines were well received and articulated the need for, challenges and best practice examples of industry engagement. The content of these guidelines confirms that the project proposed in this paper, and the work carried out within the seed project, is innovative, needed, and has the potential to lead to significant and positive change.

Management System for Engineering Education (MaSEE)

The project described within this paper advocates the development of a Management System for Engineering Education as one mechanism to increase the authenticity of engineering curricula. Within the professional environment, engineers work within a controlled management system framework which requires the application of formal protocols and processes on all projects, to maintain standards and improve outcomes. These processes relate to how work is planned (approached), controlled (progress monitored) and peer reviewed. By contrast, within the learning environment students typically have freedom to approach and control their work as they see fit. Learning support services do provide useful guidance for students wanting to improve their study skills and work-integrated learning activities enable students to experience how engineers approach their work. However, the study guidance may not be provided within an engineering context, and the effectiveness of work-integrated learning activities can vary. MaSEE identifies and exploits similarities between the professional protocols and effective learning and teaching strategies. The result is that students are given the opportunity to develop their professional identities and to approach their work as student engineers. This allows them to learn the necessary protocols, develop a broader employability skillset and, importantly, apply the protocols in a manner that allows them to engage with technical content at a deeper level.

Design verification exemplar process

A design verification exemplar process was trialled to determine if previous pilot projects could be transferred to other disciplines and institutions. Design verification is a form of peer review and is undertaken before any engineering outcomes are provided to the client. It can be considered as a peer review process for learning (Figure 1). A teaching resource consisting of a teacher implementation guide, student online module and adapted industry template were packaged for the trial. The trial involved two institutions, 4 engineering disciplines and 6 courses. For each course, an assessment task was adapted to include a design verification step, and students applied the adapted industry template. In some courses, an online learning module complemented the template. The outcomes of the trial (Foley and Willis, 2015) were assessed through a student perception survey, which used a seven-point Likert scale for responses, and showed:

- 86% broad agreement that the applied process improved the understanding of how designs are verified in industry
- 85% broad agreement that the applied process improved their understanding of the technical concepts in the course.

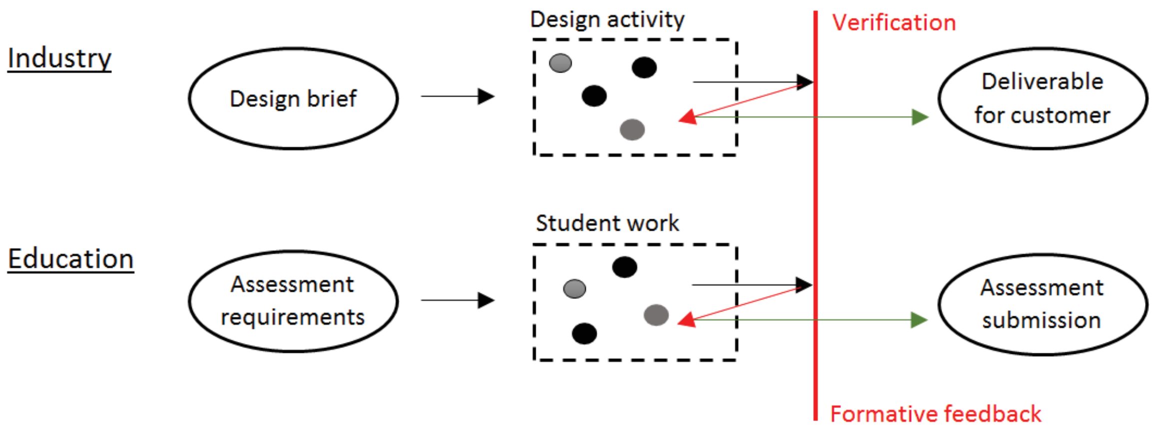

Figure 1: Design verification as cyclical formative feedback

The project team is now expanding the concept and developing resources for a further five processes through engagement with industry and further trials. The additional five processes were identified for development by the project team and relate to aspects of quality, safe design, planning, documentation and project control (Foley and Willis, 2013). This is consistent with the management system frameworks that engineers operate within, which include processes related to financial, quality, environmental and health & safety requirements. A management system in industry can include 100+ processes, to cover all business activities. However, the six processes for this project are considered to be of relevance to engineering graduates with broad applicability. These are summarised in Table 1 with respect to potential educational value and employability skills being developed.

Table 1: Identified management system processes

Industry process	Educational value	Employability skills developed
Design verification	Cyclical peer feedback	Ability to give and receive feedback / collaboration
Design review	Cyclical peer feedback	Consideration of socio-technical factors that impact work including safety / end users
Project Minutes	Tracking of group and project work	Improved teamwork Improved accountability for actions Improved meeting outcomes
Document Control	Organisation of work	Organisation of work for traceability
Project Risk Assessment	Identification of risk	Appreciation of risk factors and control measures
Project Planning	Identification of tasks and efficient project completion	Organisation and management of self, others and tasks

Industry validation

To validate the selection of processes to be adapted, an online survey was developed and released through project team networks. 43 responses were received from the professional engineers in all disciplines, distributed throughout Australia and New Zealand. Table 2 outlines the distribution of responses. The survey sought to understand whether management systems were used and which processes were most relevant to graduates. The responses indicated that all operated within a quality, environmental, health and safety or integrated management system and Figure 2 the perception of respondents as to how important it is for graduates entering an organisation to be able to operate within a management system framework.

Table 2: Distribution of industry responses (n=43)

Discipline	% of respondents*	Location	No. of respondents	Sector	% of respondents
Civil	34.9	ACT	3	Engineering consultant	32.6
Mechanical	34.9	NSW	3	Government	9.3
Electrical and Electronic	39.5	Qld	4	Large corporation/ multinational	25.6
Chemical	11.6	SA	3	Small business	5
Petroleum	4.7	Vic	5	Utility	7
Mining	14	WA	7	Other	14
Software	14	National	16		
Other	34.9	International	2		

*respondents could identify more than one discipline

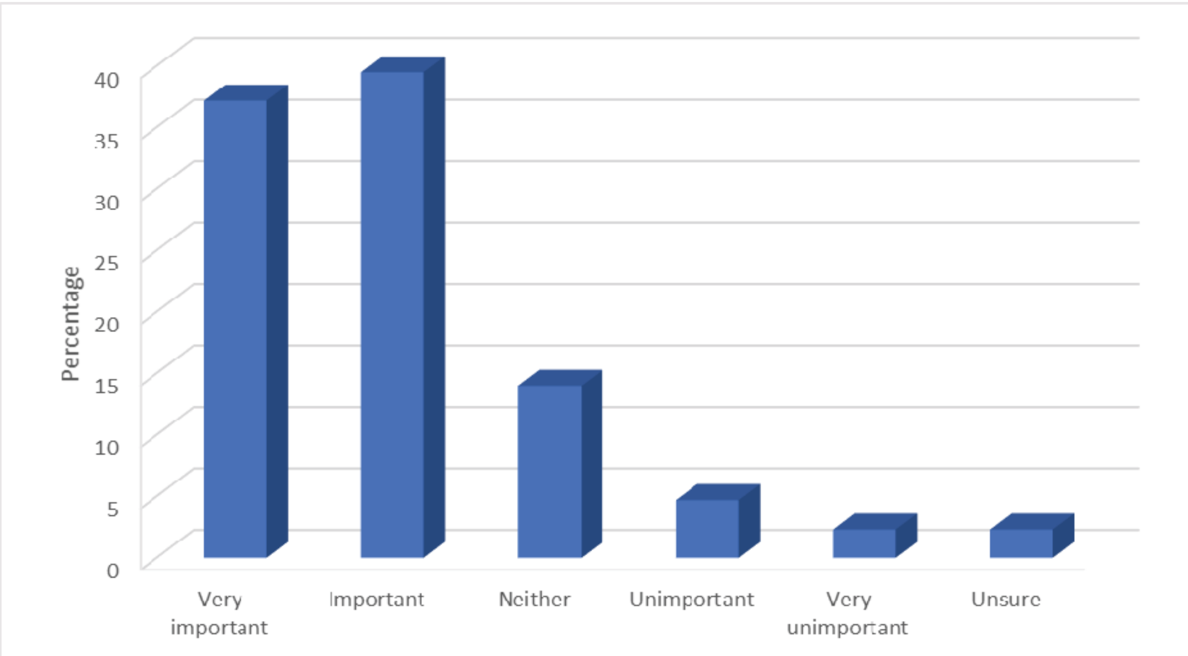

Figure 2: Importance of graduates being able to operate within a management system

The last of question results presented in this paper from the survey relates to the relative importance of the identified processes. Table 3 is less definitive and further analysis is required.

Table 3: Ranking on identified processes/activities

Processes/activities	Importance ranking (% of respondents - 1 highest)					
	1	2	3	4	5	6
Participate in design review	***25.6***	14.0	***30.2***	16.3	7.0	7.0
Undertake design verification	14.0	16.3	20.9	11.6	14.0	***23.3***
Project risk	4.7	7.0	16.3	11.6	***41.9***	18.6
Document / version control	20.9	***30.2***	11.6	23.3	9.3	4.7
Recording meeting outcomes	14.0	***27.9***	7.0	9.3	14.0	***27.9***
Project planning	20.9	4.7	14.0	***27.9***	14.0	18.6

Table 3 provides some unexpected results. The process developed initially, design verification, was not ranked as high as expected and this is being further investigated. One possible explanation is that design verification is more specific than design review and, to some, may be considered as a subset. It is also unexpected that project risk was ranked at the bottom end. This may be related to it not being the responsibility of the graduate to identify project risks. The data does show that different respondents have different views of what is and is not important for graduates.

Next steps and conclusion

Teaching resources for each of the identified processes have been developed and engineering educators are invited to trial the resources in Semester 1, 2018. The project team is seeking to understand how the resources can be used within different engineering programs.

The industry survey does indicate that an understanding of management systems is important. Further industry engagement is required to better understand the relative importance of the different processes.

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The Warman – Looking Beyond 30 Years

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SESSION C1: Integration of theory and practice in the learning and teaching process

Context

Our collective experience over 30 years of organising, fine-tuning, creating unique projects and running what has become known as the Warman Design and Build Competition (WD&B) is presented. The competition is for students in the second year of undergraduate courses in mechanical engineering, broadly defined, in Australian and New Zealand universities. The idea of running a variant of the WD&B as a high school STEM project is being considered.

Purpose

We wished to establish firm data supporting the efficacy of the WD&B and indicate ways in which the current project and competition might be promoted and extended in its reach.

Approach

Ongoing assessment of student response to the competition since its inception, and the scope of experience students gained has been conducted, over what has been a period of rapid industry transition, and links between the WD&B and the development of Engineers Australia's Stage 1 Competencies are shown.

In 2017, more extensive surveys than in the past were conducted seeking the opinions of:

- Students competing at Campus level,
- Students competing at the National Final,
- Campus Organisers, and
- Members of the Mechanical College, EA (part of a broader survey of design practice).

Results

The conclusions drawn from all surveys are highlighted with strong support and evidence for positive learning arising from the WD&B.

The adoption of the WD&B at the University of Melbourne in 2010 and reflections on their experience provide an exemplar for the continued expansion of the WD&B. It is clear the project is successful in:

- integrating practical engineering with coursework,
- developing 'work readiness', and
- providing a 'coat-hanger' to support the engineering sciences.

Conclusions

The WD&B has been an outstanding success over its 30-year life. In the changing educational world, the plan is to ensure that it continues to meet educational needs and course structures and, if necessary or desirable, make appropriate changes. The question of entering the STEM array by creating a modified 'Warman in Schools' is currently unresolved.

Keywords

Student D&B projects, Warman, Mechanical Engineering Design

Student Design and Build Projects

With the exception of 'farm kids', engineering undergraduates in the 21st Century generally have had little practical experience in engineering construction, maintenance or repair. It is no longer the age of DIY repairs to home, car or other equipment. Practical, hands-on experience has many benefits, providing relevance to the engineering-science content of typical courses and, equally importantly, helping to achieve some semblance of 'workplace readiness'. A now widely used method to promote this benefit is to use student design and build projects or competitions as part of coursework. Careful consideration and good judgement are needed to ensure that such projects justify the course time they expend. Careful matching of project complexity and assessment of their learning benefits is also essential, as is the need for fresh new projects, year by year.

As discussed in (Smith 2013), *"from an engineering educator's perspective, the purpose for presenting students with project-based experiential learning scenarios in a curriculum is to replicate real world activity in the profession they have chosen. Many authors have addressed these issues (including (Dym, Agogino et al. 2005); (Counce, Holmes et al. 2001); and (Dutson, Todd et al. 1997)). In such projects, students are given an opportunity to safely develop their domain and professional skills and grow in confidence and experience. Students are led through processes of divergent and convergent thinking while applying basic science and engineering principles. This naturally sits well with university education which seeks to equip students with the ability to respond to open problems and uncertainty which while pushing them beyond their comfort zones prepares them for their future."*

The Warman Design and Build Competition Described

The Warman Design and Build (WD&B) is an experiential, systems realisation challenge. The WD&B provides a unique project-based problem-solving experience annually for teams of nominally four second-year mechanical-engineering students in Australasian universities. The project takes place on two levels, initially across individual campuses and then at a 'National Final'. The Final, typically run over three days, brings together winning teams from participating universities. While focused on mechanical engineering, some students from other disciplines participate because various streams undertake common design courses.

Considering the impact of the project, approximately 2,500 students in 20 universities experienced the WD&B in 2017. It follows that over 30 years it has influenced the education of tens of thousands of engineers, while directly supporting many academics who have implemented the project at their own universities.

Devising of the original project tasks and rules for each season is not a trivial creative task. The requirement is to design and implement a project for the engagement of all students that challenges the 'best-of-the-best' (at the National Final) yet stimulates and excites ingenuity at the local level without discouragement. It is important to ensure that tasks are open to multiple competitive design concepts and different solutions. Therefore, some apparent ambiguity in the formal project specification is intentional while clearly defining which boundaries should not be crossed. Consequently, the devices at the National Finals typically represent widely different concepts. The fact that the best teams across 20 campuses have not converged to the same solution reaffirms the evolved strategy.

Cost and student skill levels are considerations in writing the rules. Each campus takes a different approach but the rules state students shall manufacture their prototype device themselves using commonly available materials, components and methods. The production skill exhibited between teams varies greatly as does the investment made. However, at whatever level a team becomes involved, significant learning has always been clearly demonstrated. Feedback from stakeholders indicates that students achieve key learning outcomes as they tackle technological, fabrication and integration issues, possibly for the first time. This can be as simple as students learning to work with friction. When they want it, they cannot get enough and when they do not want it, there is always too much. Campus organisers have found it satisfying to watch students engaging in valuable peer-to-peer learning, teaching each other about aspects without prior formal instruction on them. This is clear evidence of the growth in both maturity and technical competence of the students.

In establishing the rules, the real objective for the device performance is based on a unique scoring algorithm. A range of measures is used including mass, size, speed, reliability and transport efficiency. Over time, the algorithms have become more complex. This has been a conscious decision to challenge all students to make some value judgments about their target score and their realisation capabilities. With the rules expressed in the context of designing for use on the mythical planet Gondwana, students are sometimes confused by a client value system, which is at odds with their own. While this is not as evident at the National Final, at the campus level it has caught some teams out, teaching a valuable lesson about listening to the voice of the customer. Through observation, and sharing across teams, albeit in a competitive environment, this and other similar lessons can also be taught to the whole class. When students find the going tough, they do accept reassurances that they are investing in their future, that nothing of value is easy, and that they need to balance the difficulties with the positives. At the end of the experience, almost all students acknowledge that they learned a lot about themselves as well as about design, that they benefited from being pushed outside their comfort zones, and that they had fun in the process.

Details of universities which have competed over the years, together with much other data for the Competition, may be found in (Churches and Smith 2016). As shown in Table 1, the maximum number of campuses competing in any year was 24, in 1995. The lowest number of competing campuses was 14, in 1989, 2008 and 2010. The campuses of the UNSW Canberra (at ADFA), Adelaide, and Newcastle have been the most consistent participants, with 29 attendances at National Finals. The average number of participating campuses over the Competition's history has been 17.6.

Universities returning in 2017 after a significant break are CQU, QUT and University of Tasmania. The University of Tasmania entry though is from the AMC (the Australian Maritime College) that represents a first time involvement for this campus. While foreign campuses of Australian universities have been involved in the past (Monash Malaysia and UTS Singapore), 2017 sees Shandong University from China representing the first independent entry beyond Australasia in 30 years.

Measuring Effectiveness

In essence, the objective of the WD&B has been to assist Universities offering Mechanical Engineering programs (broadly defined) to produce more rounded undergraduate student capability. It does this by providing a complete practical exercise requiring creative conceptual design, leading to prototype construction, testing, refinement, reconstruction (manufacture) and proof testing. It is no accident that the skills built up in the WD&B closely match Engineers Australia's (EA) Stage 1 Competencies and that the students perceive these competencies being developed through the WD&B project. This coincidence is a powerful argument for the Warman to be considered as part of any undergraduate Mechanical Engineering program, preferably coinciding with the first course in design analysis. An indication of how closely the WD&B relates to the Stage 1 Competencies is given in Table 2. Engineers Australia considers the WD&B a benchmark project for enlightening our undergraduate cohort in engineering whole-of-life processes.

The testimony of RMIT students at a national final is encouraging and representative. They wrote: *"from when we began the project many months ago (at RMIT) up until the last roll of the dice on Sunday afternoon (at the National Final), we've learnt so much that we feel will be invaluable as we advance through our engineering degrees and in turn careers. … (the WD&B) will help to shape us as engineers for the future."*

Table 1: Participation in the Warman Design and Build Competition

UNIVERSITIES Participating		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	TOTAL at NF	18	14	18	18	20	17	22	24	21	21	18	18	16	18	16	18	17	20	16	17	14	17	14	15	16	17	15	15	17	18
	COUNT at NF																														
Australian National University	**3**																														
Auckland University of Technology	**2**																														
Central Queensland University	**19**																														
Charles Darwin University	**4**																														
Curtin University	**14**																														
Deakin University	**3**																														#
Flinders University	**7**																														
Griffith University Gold Coast	**3**																												#		
James Cook University	**22**																														
Massey University, NZ	**5**																														
Monash University	**27**						#										#														
Monash University - Caulfield	**15**																			Closed Engineering Program											
Monash University, Malaysia	**10**													#	#	#		#	#	#	#			#	#						
Queensland University of Technology	**17**																														
RMIT University	**25**																														
Swinburne University of Technology	**12**																														
University of Adelaide	**29**																														
University of Auckland, NZ	**24**																														
University of Ballarat	**7**																														
University of Canterbury, NZ	**26**																														
University of Melbourne	**8**																														
University of Newcastle	**29**																														
University of New South Wales	**25**																					#									
University of NSW, Canberra (at ADFA)	**29**														#																
University of Queensland	**18**																														
University of South Australia	**21**																														
University of Southern Queensland	**21**																														
University of Sydney	**7**												#																		
University of Tasmania	**18**																														
University of Tasmania (AMC)	**1**																														
University of Technology Sydney	**22**																														
UTS - Singapore	**1**																														
University of Western Australia	**25**																														
University of Wollongong	**10**																														#
Victoria University	**12**																														
Shandong University, China	**1**																														

 # - Participated at Campus level but not at the National Final

Table 2: Engineers Australia's Stage 1 Competencies and How the WD&B Builds Capacity in the Elements of Competencies

Stage 1 Competency and Elements of Competency		How the Warman Competition Builds Capacity
1.	**KNOWLEDGE AND SKILL BASE**	
1.1.	Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.	Students apply engineering fundamentals to systematically investigate and analyse a complex engineering problem, with the aim to develop an innovative and practical solution.
1.2.	Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.	Students develop and apply relevant investigation analysis, interpretation, assessment, prediction, evaluation and measurement tools to evaluate the performance of their solutions.
1.3.	In-depth understanding of specialist bodies of knowledge within the engineering discipline.	N/A
1.4.	Discernment of knowledge development and research directions within the engineering discipline.	Students interpret and apply selected research literature to inform their conceptual designs, material selection and methods of construction of their prototype devices.
1.5.	Knowledge of contextual factors impacting the engineering discipline.	N/A
1.6.	Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.	Students apply systematic principles of mechanical engineering design to develop their solutions and gain a real-life understanding of the fundamental principles of engineering project management. Students appreciate the principles of risk management and the health and safety responsibilities of a practical engineering problem during construction, commissioning and operation.
2.	**ENGINEERING APPLICATION ABILITY**	
2.1.	Application of established engineering methods to complex engineering problem solving.	Students learn to partition the set problem into manageable elements for the purpose of analysis and design, and then recombine to develop a functioning solution in the form of a prototype.
2.2.	Fluent application of engineering techniques, tools and resources.	Students apply a wide range of engineering tools for analysis, simulation, visualisation and validation of their designs. These tools are often taught concurrently in the course. Students design and safely conduct experiments, analyse and interpret data, and formulate conclusions in relation to the performance of their prototype systems.
2.3.	Application of systematic engineering synthesis and design processes.	Students proficiently apply technical knowledge and open ended problem solving skills to design various elements of the prototype system to satisfy the competition specifications.
2.4.	Application of systematic approaches to the conduct and management of engineering projects.	Students work in teams to execute a relatively complex engineering project and become aware of the need to plan and quantify performance over the life-cycle of the project.
3.	**PROFESSIONAL AND PERSONAL ATTRIBUTES**	
3.1.	Ethical conduct and professional accountability	N/A
3.2.	Effective oral and written communication in professional and lay domains.	Students build capacity in communication with their peers, including comprehending critically and fairly the viewpoints of other team members, and expressing their own information and ideas effectively and succinctly. Courses often include the requirement to submit a written report and oral presentation as part of the project assessment.
3.3.	Creative, innovative and pro-active demeanour.	Students apply creative approaches to identify and develop alternative concepts and solutions, often from both technical and non-technical viewpoints.
3.4.	Professional use and management of information.	N/A
3.5.	Orderly management of self and professional conduct.	N/A
3.6.	Effective team membership and team leadership.	Students are required to work in a team environment of nominally four members. This exposes students to the fundamentals of team dynamics and leadership, learning to earn the trust and confidence of their colleagues, and recognising the value of alternative viewpoints.

Surveys have been conducted over the years of the opinions of students who have completed the WD&B and of design-lecturing staff at the various competing universities (the Campus Organisers). References to the bulk of these surveys pre 2017 and prior history can be found in (Churches 1989), (Magin and Churches 1992), (Magin and Churches 1994), (Field 1997), (Churches and Magin 1998), (Churches and Magin 2003), (Churches and Magin 2005), (Smith 2007), (Smith 2008), (Smith 2013) and (Churches and Smith 2016).

Students and campus organisers have been unanimous in indicating that the project makes important contributions to student learning in many respects, e.g. how to work in groups, the importance of simple design, and the practical experience of design. Each University uses the WD&B framework differently with respect to student assessment and the support students receive. However, all campus organisers agree that the activity supports their learning objectives very well. In the benign environment of the competition, both success and failure are turned into effective design learning outcomes.

In 2017, more extensive surveys were conducted gauging the opinions of:

- Students competing at Campus level (198 responses),
- Students competing at the National Final (53 responses),
- Campus Organisers (13 responses), and
- Members of the Mechanical College, EA (part of a broader survey of design practice).

Consolidating student data from similar surveys, collectively provides 1613 responses from those engaged in the WD&B from 1991 to now. The picture is very positive, as depicted in Figure 1[1]. The lowest "yes" response to "Did your experience of participation in the WD&B result in learning in …?" across a large range of issues is 67% with the highest being 86%.

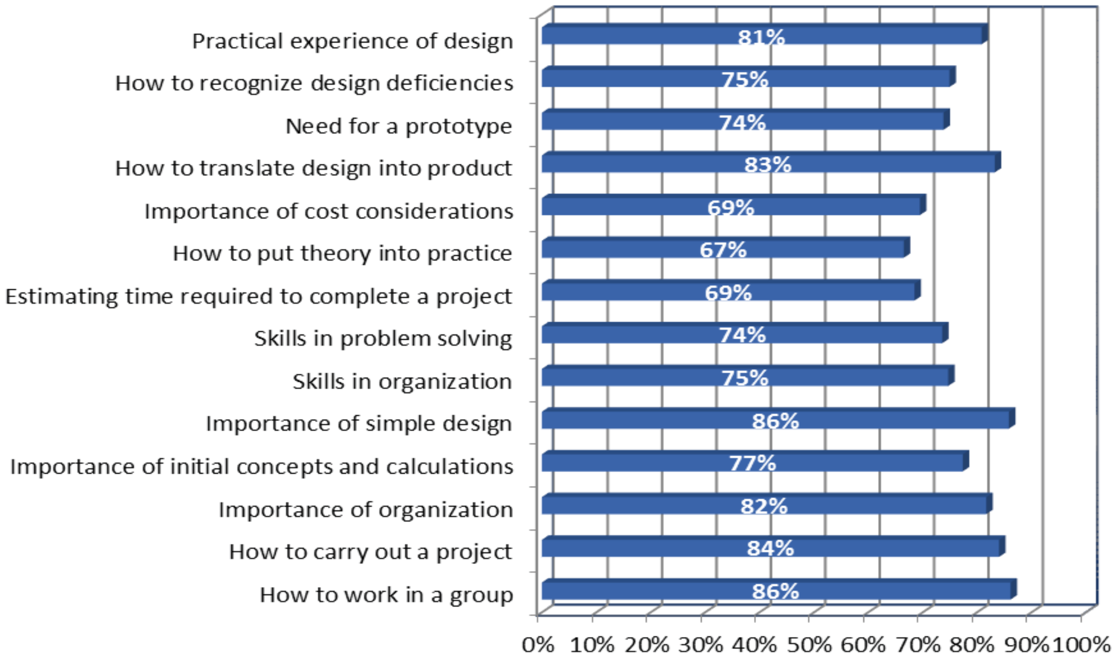

Figure1: Student survey responses of "YES" to "Did your experience of participation in the WD&B result in learning in each of the aspects listed?" (significant or some)
(responses marked 'little', 'unable to say/unsure/blank' or 'no/none' account for the remainder)

[1] Data: 2017 (N Finalists, 53), 2017 (National Survey, 198), 2016 (N Finalists, 64), 2015 (N Finalists, 54), 2014 (N Finalists, 50), 2010 (N Finalists, 44), 2004 (N Finalists and 3 campuses, 328), 2002 (National Survey, 345), 1997 (National Survey, 318), 1993 (UNSW, 87) and 1991 (UNSW, 72).

In 2017, the effort in reaching out to the Mechanical College members was to document College member views held of Engineering Design in general and the WD&B in particular. Questions asked and responded to by 159 members included:

- Do you consider your university program provided you with an adequate foundation in the PRACTICE of Engineering Design? - 122 said “yes”.
- What percentage of your working time is related to Engineering Design? – The average of responses was 44% but with 26 respondents identifying zero.
- What percentage of your working time is devoted to actual Engineering Design? – The average of responses was 24% but with 41 respondents identifying zero.
- Did you participate in the WD&B at the Campus Level (conducted 1988-present)? – 80 said “yes”.
- Did you participate in another significant ‘Design and Build’ activity? – 16 said “yes”. Responses included FSAE, SAE Baja, Solar Boat Challenge and a range of thesis and work related projects.

The 80 Mechanical College members that experienced the Warman were also asked to respond to the same instrument used with students since 1991 and summarised in Figure 1. The results for the college members are shown in Figure 2 where the banding of positivity in reflection towards the WD&B spans 61% to 93%. In both cohorts the highest ranking “yes” response was for learning how to work in groups. The importance of simple design was also highly rated by both. In contrast, the importance of cost as a learning outcome was lowly rated by both. Perhaps this highlights the efforts of the national organisers to eliminate the financial investment of students as a discriminator of system performance in the WD&B.

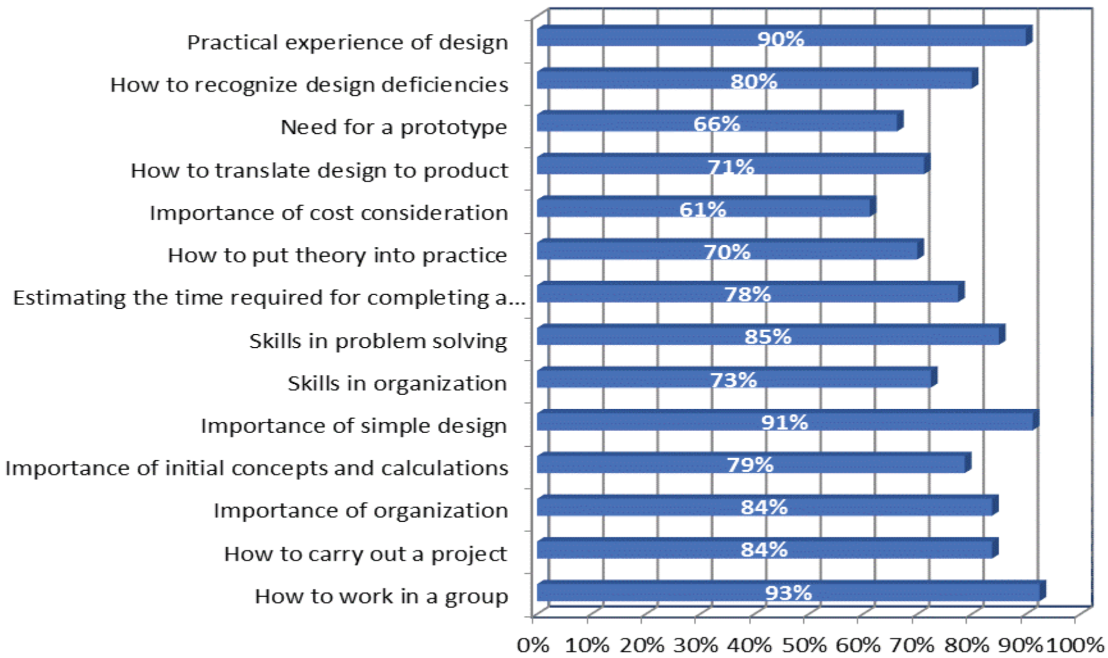

Figure2: Mechanical College responses of “YES” to “Did your experience of participation in WD&B result in learning in each of the aspects listed?” (significant or some)
(responses marked ‘little’, ‘unable to say/unsure/blank’ or ‘no/none’ account for the remainder)

In further reflection (for those Mechanical College members who experienced the WD&B):

- Do you consider the WD&B experience valuable to you? – 73 of 80 said “yes”.
- What do you remember most about your WD&B experience? – many comments were provided including one from a 2002 participant which read: “*It was real, and results*

depended on something actually working, not the theory. You could invest a lot of time into something only for it to be wasted. You needed to put a lot more effort in to get it to work. The camaraderie of our team mates was also brilliant, as was the competition and rivalry aspect."

- Please comment on how the WD&B experience has impacted your design thinking? – again, many comments were provided including from a 1993 participant: *"It reminds me of what failure looks like, and how to avoid it."* It is noted that not all students are successful in the competition aspect of the WD&B but learning can still be achieved.
- Can you connect your WD&B experience in anyway with your subsequent engineering career? – While some indicated not really in a direct way, a perceptive comment in respect of tacit knowledge came from a 2002 participant who said: *"Not consciously, but I think it definitely helped."* Others were more explicitly positive stating "*I'm still using that experience (1997)*", and that it helped them in "*working as a team, and the need to be resourceful (2000)*".

The distribution of the 80 Mechanical College respondents' WD&B experience across the 30 years of the competition is shown in Figure 3. The mode fell on 2000 with 6 and two respondents failed to identify their year of involvement. There were only three years of the competition unrepresented in the sample, namely 1988, 1990 and 1995. Of the 80 respondents, 23 identified themselves as also being National Finalists.

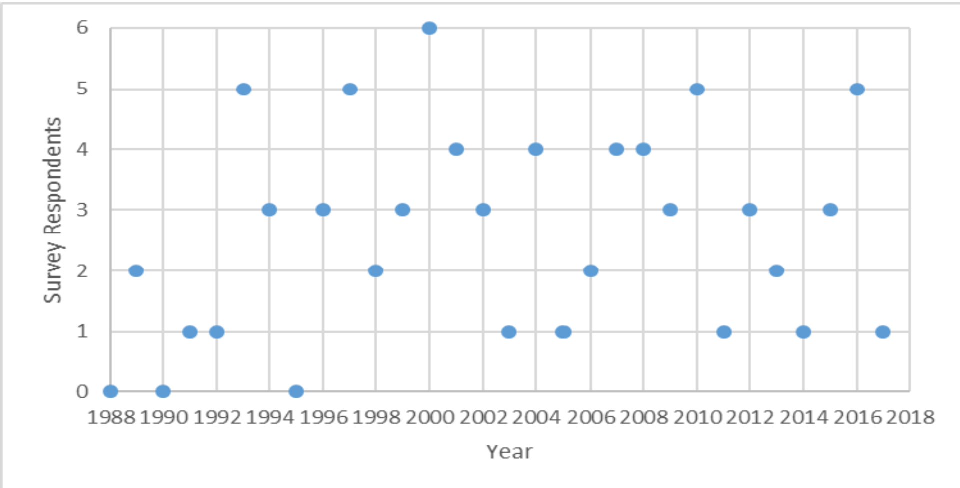

Figure3: Mechanical College respondent involvement in the WD&B across 30 years

Reflections on the University of Melbourne Experience

As shown in Table 1, The University of Melbourne first engaged in the WD&B in 2010. Reflections on this decision to enter the competition (in the competition's recent history), and the subsequent experiences of Melbourne's students highlight messages and lessons for further expansion of the project to other universities.

In 2008, the University of Melbourne introduced the 'Melbourne 3+2 Model'. It consists of a 3 year Bachelor's degree (in 'Design' or 'Science' for Mechanical Engineers) followed by a 2 year Master's degree. (As a recent experience in major course revision, it may provide useful data on design-learning issues.) Design is first taught in the second semester of year 3 in the BS capstone course (MCEN30014) with over 200 enrolled students annually. Design as a disciplined activity is then built upon through the Masters. With the introduction of the 'Melbourne Model' came the opportunity to innovate the design teaching and learning curriculum. The School of Engineering academic executive understood the importance of practical experiences in concept realisation, and this enabled the design discipline leader to successfully negotiate the inclusion of WD&B into the mechanical engineering curriculum, entering the National Final for the first time in 2010.

The design leader, like many involved with the WD&B is passionate about design and preparing students for their professional industry careers. Students typically do not find design easy. There is often no right or wrong answer. Focusing upon experiential learning and the integration of student theoretical understanding blends content from other disciplines, such as statics, dynamics and strength of materials, to achieve realistic goals. Students need to work in teams, and this offers a distinct set of possibly new soft-skill challenges and opportunities. A WD&B assessment task associated with team development reflections encourages student engagement. Students are introduced to the research of Bruce Tuckman and Meredith Belbin as a foundation conceptual framework for teaming.

Within the BS program, students have few practical experiences (i.e. design, build, trial, revisit design) in the prerequisite subjects. This deficit has the potential to be detrimental to student experience in the eight-week WD&B that is the team-based focus of this subject. Despite concerns about students resenting the lack of a graded skill development program within the overall Bachelor course, student feedback for the WD&B is positive.

Optional seminars are scheduled outside normal lecture times for students who have no prior experience but are interested in additive manufacture (3D Printing) and inexpensive controller programming (Arduino). The emphasis to the student cohort is that the use of these technologies is not mandatory but rather an option that the team can choose to pursue.

Melbourne students, in the main, have appreciated that the WD&B offers an engineering experience closer to the ‘real world’ than has been offered anywhere in their prior studies. It is emphasised to the student cohort that performance in the WD&B trials have little bearing on overall honours calculations. The students are told from the outset and repeatedly that 100% for all the three written tasks (Initial Appreciation, Morphological Analysis, Final Report) and a minimum finite WD&B trial score would earn a minimum of 80% corresponding to first class Honours. The WD&B is valued at 50% of the overall subject (with two other minor assignments and a 40% exam). These weightings give the student a strong indication from coordinating staff, and the School of Engineering as a whole, that *“WD&B is important”*. The associated pedagogy, where the student is given the twin messages, *“Practical design realisation experiences are critical to your professional development”* and *“There is no need to be anxious about the impact of your performance during WD&B trials on your overall course honours calculation”* is critical to student engagement.

In fact, the overall marketing aspect of the WD&B experience cannot be overvalued. This includes marketing to the students, to colleagues, to the many managers in the academic world who are at best advocates, but who must never be allowed to be less than neutral about the program. It is nigh impossible for School of Engineering academic executives to be anything but supportive when the arguments associated with WD&B are articulated.

- Marketing the WD&B to teaching and learning academic executive: *“If every student were able to realise a design that completed the task perfectly, we could be confident that coordinating staff have compromised the learning opportunities available from a more challenging task that necessitates more struggle from more students.”*
- Marketing the WD&B to the fabrication workshop manager: *“Open your doors and let me fill your workshop with students. Any future review of your workshop cannot but identify the essential design-realisation support function.”*
- Marketing the WD&B to academic colleagues: *“The WD&B does cost a lot more than the average subject, but WD&B will offer our students an advantage in the competitive job market for graduate engineers.”*
- Marketing the WD&B to university leadership not currently participating: *“The WD&B is an exclusive elite club that any Engineering School can join.”*

- Marketing the WD&B to colleagues considering whether to champion the introduction of WD&B: *"In this era, practical skills that can facilitate a successful graduate career are ascendant. There is evidence that university engineering executives are searching for means by graduate competitiveness can be enhanced. The WD&B is one opportunity. In addition, there is evidence in this era in Australia that career progression can be achieved through academic leadership of practical and professional 'soft' skill development in the student cohort."*

Of course, the evangelical message has to match the audience. However, at the University of Melbourne, the WD&B is now fully embedded with future planning for 'Fab-Lab facilities' predicated on supporting the WD&B experience. It is being used as a foundation success from which other departments and disciplines are encouraged to launch their own design-realisation initiatives.

A final reflection is that the performance of the majority of systems is not great but students are always congratulated for participating and reminded of the underlying active learning pedagogy from which profound learning outcomes are available from WD&B. For example, from communications with 2017 students following the WD&B Melbourne trials:

Dear MCEN30014 Student,
Congratulations to all teams on the endeavour, blood-sweat-and-tears, and struggle that was on display during the Warman Performance Trials this afternoon!
As I stated at the start of the semester, the actual performance of your device will not have a significant impact on your overall course outcome in MCEN30014 but it is an excellent opportunity to learn practical issues associated with our profession. The 'biggie' is that, in practice, what we design eventually has to be built, or more generally, 'realised'. Everyone now has a deep understanding of this fundamentally important concept. … Thanks to all those who supported the Warman Performance Trials this year! … (especially those who) offered students many learning outcomes, some simple and others subtle.
Of great importance, I know that many of you have been made aware of appropriate behaviour in potentially dangerous environments, especially with respect to Occupational Health & Safety (OH&S) requirements. This learning will serve you well in your future careers.
It is my personal opinion that the 2017 Performance Trials has offered MCEN30014 students an excellent 'Warman' active learning experience. Again, congratulations to you all! CB

Dear MCEN30014 student,
Following the 'crescendo' of last Thursday, … Each and every team that was able to place a device at the start zone of the track (irrespective of what happened next) should feel proud. You rose to the challenge, dealt with the steep learning curves of designing and fabricating a complex system, and likely learned many important lessons along the way. CB

Looking Forward

As discussed in (Churches and Smith 2016), the life of the WD&B has seen marked changes in Australia's university system. One of the most significant has been an increasing emphasis on research, with university funding heavily linked to research outcomes. We conclude and believe the result has been a focus on educating graduates in 'engineering science' to the detriment of 'engineering practice', with practical engineering design the big loser. Whilst Engineers Australia's National Committee on Engineering Design (NCED) believes there is sufficient current pressure, through the EA Accreditation process, to increase the practical engineering content of Australian engineering courses, in 2018 and beyond the need for the WD&B experience is as great as it has ever been.

The WD&B has moved with the times. From the specification of a purely mechanical device in its first few years, projects are now written to be suitable for inclusion in mechatronics courses, while still not excluding purely mechanical devices. There remains keen interest from the Campus Organisers and the student cohort present at each National Final is judged to be as enthusiastic as were those in 1988.

Warman in Universities

The aim of the WD&B competition is to present a challenge that requires students to conceive, develop, implement and test a mechanical system (a machine) in a way that can be integrated within the coursework of their first undergraduate engineering design course, whether mechanical, mechatronic or any other mechanical specialisation. The WD&B competition greatly assists Universities offering Mechanical Engineering programs (broadly defined) to build undergraduate student capability in Engineers Australia's (EA) stage one competencies by providing an exercise that requires students to develop and apply many of these competencies in a practical situation.

Furthermore, developing 'work readiness' skills for graduates is a mandate for all universities by the employers of their graduates. The WD&B competition exposes students to the reality of their engineering discipline by exposing them to open-ended problems and uncertainty, enhancing a student's ability to transition into the workforce. The nature of the design and build team project often pushes students beyond academic and social comfort zones, enabling students to develop and enhance skills in a safe learning environment, where team dynamics and design errors do not result in costly or potentially dangerous outcomes.

In addition to the student benefits, the WD&B competition provides a unique opportunity for Campus Organisers to meet and collaborate with other engineering design educators. A forum is held as an integral part of the National Final's weekend where engineering design educators share teaching methods and resources, meet key representatives of Engineers Australia's Mechanical College Board and members of the National Committee on Engineering Design. These networking opportunities provide important links between academics and representatives from industry and Engineers Australia.

Warman in Schools

There is the possibility of extending the reach of 'the Warman' into secondary schools, as part of the available 'STEM' array aimed to excite high school students towards science and engineering careers. The concept is to run a simplified WD&B competition based on the preceding year's university rule set focused on years 10 and 11. This would include universities making tracks available and offer opportunities for university students to be part of a mentoring program. A small-scale pilot engaging Adelaide Schools was run in 2015. It was initiated and implemented by A/Prof Sandy Walker, of Flinders University, with support from EA's NCED. An attempt was made to expand the project to more schools with the other Adelaide universities involved in 2016, but achieving traction proved difficult. As with any successful outreach activity, it becomes dependent on supportive school principals, enthusiastic teachers and available university staff and students. It is believed that if the framework is built, the high school students will come. Weir Minerals (the principal sponsors of the WD&B) enthusiastically support the 'Warman in Schools' concept but a method for delivery with limited resources remains an uncertain future aspiration for NCED.

Conclusion

In general, the immediate future of the University based WD&B looks secure. However, in a rapidly changing educational environment, with pressure from rapidly increasing course content and changes in engineering technology, it seems clear that the WD&B will need constant vigilance, ongoing creative input and 'tweaking' if it is to maintain its present and to date enduring useful role. Ensuring that outcome requires maintenance of a strong, enthusiastic and creative National Committee on Engineering Design.

The WD&B has been an outstanding success over its 30-year life. In the changing educational world, the plan is to ensure that it continues to meet educational needs and course structures and, if necessary or desirable, make appropriate changes. The question of entering the STEM array by creating a modified 'Warman in Schools' is currently unresolved.

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Evaluation of a redesigned Engineering degree founded on project based learning

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CONTEXT: In 2012, Massey University of New Zealand offered a redesigned Bachelor of Engineering (Hons.) [BE (Hons.)] degree, using a curriculum based on the CDIO standards (www.cdio.org). It was redesigned at a time when the School of Engineering and Advanced Technology (SEAT) at Massey University had embarked on a strategic review of its offerings, and it replaced a well-established engineering programme. The Project Based Learning (PBL) 'project spine' was introduced, which consisted of a series of PBL courses throughout the BE (Hons). This was intended to address the need for graduates who are 'rounded' with stronger professional skills.

PURPOSE: This study was undertaken to determine whether the change to the structure of the BE (Hons.) programme had increased the alignment of graduates' skills with the Washington Accord Attributes, particularly regarding professional skills, thereby increasing the relevance of the graduates to employers.

APPROACH: With ethics approval, this study was conducted using an anonymous on-line survey sent to the final year cohort of students following final examinations. This was done for the last cohort of students prior to the redesign and, for the first two cohorts after the redesign was implemented. The survey included questions rated using a Likert scale. Open-ended questions were also asked. Primary feedback was sought on a self-evaluation against the graduate competencies. Feedback was also sought on teaching, evaluation of the degree for the graduate competencies, feedback on assessments, staff and overall experiences. Staff that supervised individual student final year projects were also sent an anonymous on-line survey, where staff evaluated the supervised student against the graduate attributes using a Likert scale. Results for the three years are reported, including a statistical analysis of Likert scale questions, comparing the differences between means and testing for significance. Open-ended questions were reviewed to provide qualitative analysis of the data.

RESULTS: Although histograms of the self-evaluation responses by students rating their competency against the graduate attributes would suggest that the cohorts following the redesign rate themselves more highly for each attribute, statistical analysis suggests that the only significantly improved attributes (at 0.05 significance) are of a student being able to design solutions for complex engineering problems and their ability to assess societal, health, safety, legal and cultural issues. In comparison, histograms of staff evaluations do not suggest any differences in cohorts. However, analysis shows that students in the redesigned BE (Hons) programme are able to apply ethical principles and commit to professional ethics better than previously. Results suggest that the redesigned programme has a better balance of practical work and theory (at 0.05 significance), but the rate of feedback on assessments is worse compared with the old structure (at 0.05 significance). Overall students do not rate the restructured degree worse or better than the older degree.

CONCLUSIONS: Qualitatively, the redesigned BE (Hons) appears to give students more confidence in their ability as Professional Engineers. It is significant that their judgement of professional skills around applying engineering solutions to societal and cultural concerns has improved. It is also significant that the balance of practical and theoretical aspects of the degree appear to have improved, showing that a PBL-based engineering degree is assisting in reducing the gaps between original graduate attributes and the required graduate attributes. Further surveys of cohorts using more targeted surveys will confirm whether this is the case.

KEYWORDS : Project-based learning, engineering graduate attributes, soft skills, professional skills

Introduction

Massey University of New Zealand offered a redesigned Bachelor of Engineering (Hons.) [BE (Hons.)] degree, using a curriculum based on the CDIO standards (www.cdio.org), in 2012. A strategic review in 2010 of Massey University's School of Engineering and Advanced Technology's (SEAT) offerings resulted in the redesigned degree designed to ensure it offered a unique learning experience. The redesigned degree was aligned to revised accreditation criteria of the Institution of Professional Engineers of New Zealand (IPENZ). IPENZ had developed a National Engineering Education Plan, released in 2010 (IPENZ, 2010), which had identified the graduate attributes required from engineering education to increase the relevance of graduates' skills to what employers required and aimed to reduce the gaps between graduate attributes and professional competencies of the International Engineering Alliance (IEA, 2013) and the then current IPENZ accreditation criteria and graduate profile (Anderson and Goodyear, 2011). The curriculum architecture was developed with the consultation of faculty, industry, students and alumni, using focus groups and can be conceptualised as shown in Figure 1:

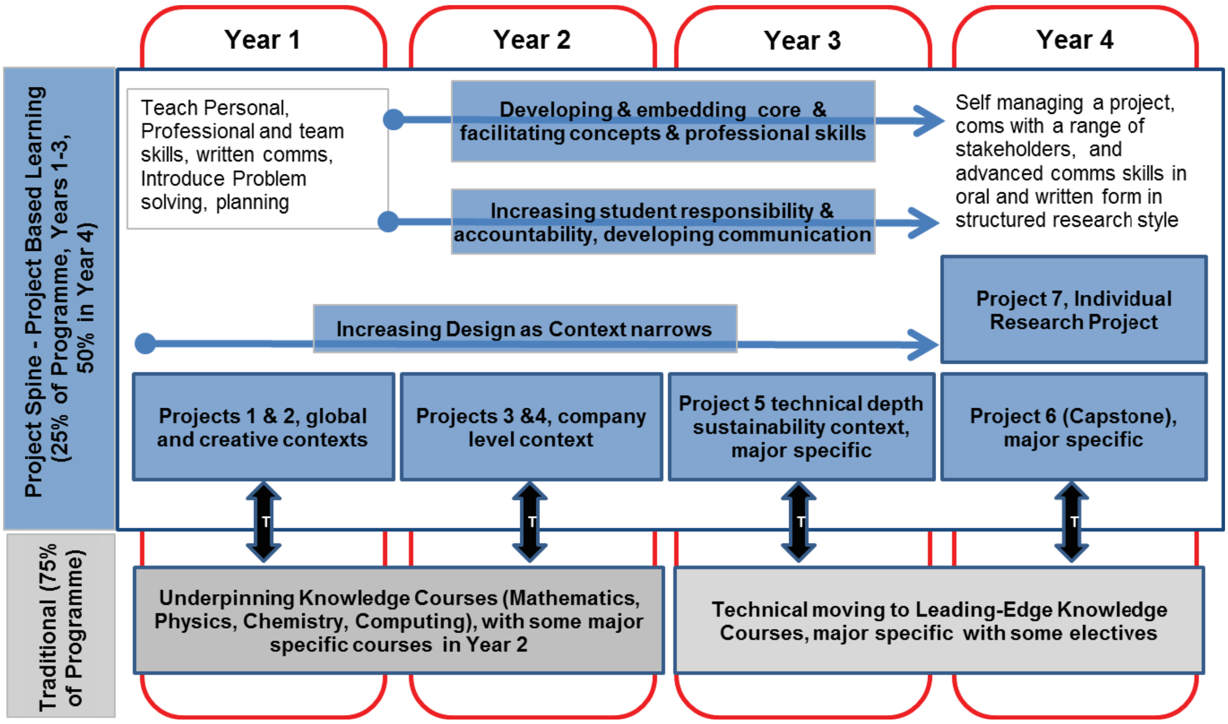

Figure 1 The BE (Hons) Curriculum Structure - post 2012

Before 2012 there were 15 majors within the programme but this was reduced to 4 following the redesign. The old programme, that had been in existence and evolved over 40 years, had a series of projects across the 4 years, but these were largely associated with specific papers (or subject areas). There was no serious intent to integrate subject areas - at least until the final year. For most engineering options there was a final year double semester 'design project,' which varied from major to major and could be individual or team based. There was no specific emphasis on the development of 'soft' or professional skills though some courses may have emphasised them at times. The new programme has a:

- Focus on project based learning in teams across all 4 years (25% of the programme)

- Where the projects are designed to integrate and apply knowledge learned in a specific year and,
- Where the projects are designed to introduce and embed problem solving principles in a range of contexts, and
- Where complexity and autonomy increase across the 4 years - leading to the final year capstone and research projects

The Project Based Learning (PBL) 'project spine' adopted by the redesigned programme was intended to address the need for graduates who are "rounded" with stronger "soft" or professional skills around teamwork, ethical considerations, sustainability, management and leadership, life-long learning and have a greater practical appreciation of the theoretical knowledge that they were being taught, as this mode of learning is believed to develop these skills more than a traditional learning approach (Mills and Treagust, 2003, Hadim and Esche, 2002). Project-based Learning in each year of an engineering programme is seen as the fourth principle towards guiding the transformation of Engineering Education for the greater engagement of students (Beanland, D; Hadgraft, R.; Mulder, KF; Desha, C.J.; Hargroves, K.J.; Howard, P. & Lowe, D., 2013). The 'project spine' has also allowed a practical implementation of the CDIO syllabus in this redesigned degree (Anderson and Goodyer, 2011).

The study aimed to evaluate changes in our graduates' proficiencies before and after the redesign, and identify areas for further improvement, using online surveys of both students and staff who had supervised those students. The study should also show whether the change to PBL has been effective in addressing the required professional attributes of an engineering education and will be of relevance to those in engineering education looking to introduce PBL.

Methodology

Students who had completed their Bachelor of Engineering in 2014, 2015 and 2016 were invited to take part in an online survey. The 2014 cohort had completed their degree prior to the degree redesign, while the 2015 and 2016 students completed the redesigned degree. In addition, staff who had been supervising these students during their final year project were also asked to evaluate their students' ability against the graduate attributes. The purpose of this was to provide an independent view of student performance from a staff member who had worked closely with the student on a yearlong project. This research was reviewed and approved by the Massey University Human Ethics Committee, Application SOB 14/51. The survey was administered independently and all identifying information was removed before the researchers were given access to the data.

The questions are based on the graduate attributes taken from the Washington Accord (the use of which is seen as the first principle in guiding the Transformation of Engineering Education, Beanland, D. *et al.* (2013)). These attributes are used by IPENZ for accreditation.

Students were asked to evaluate their ability in relation to each of the graduate attributes listed in Table 1. They were then asked to evaluate how well they felt the Massey University Engineering degree prepared them to achieve each of the attributes. Both of these questions were rated on a five point Likert scale with the options strongly disagree, disagree, neither disagree nor agree, agree, and strongly agree available for selection.

The following statements were then rated using the same Likert scale to gain further feedback:

In general the quality of lecture was high

In general the quality of practical exercises (e.g. labs) was high

The balance between lectures and practical exercises was about right

The balance of final exams and assessments during the semester was about right

The rate of feedback on your assessments was acceptable

The quality of feedback you received for your assessments was acceptable

Staff are experts in their fields

Staff are able to effectively communicate their expertise

Staff are friendly and approachable

The students were asked how they would rate their overall experience at Massey University and what the likelihood is that they would recommend Engineering at Massey University to others. These statements were rated using the Likert scale of poor, fair, good, very good and excellent.

Table 1: Graduate attributes used in survey

Key aspect referred to in this paper	**Full description given in survey**
Apply knowledge	Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialisation to the solution of complex engineering problems.
Analyse	Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
Design	Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
Investigate	Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
Create	Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities, with an understanding of the limitations.
Societal	Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems.
Sustainability	Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts.
Ethics	Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
Teamwork	Function effectively as an individual, and as a member or

Key aspect referred to in this paper	Full description given in survey
	leader in diverse teams and in multi-disciplinary settings.
Communicate	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
Management	Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

The staff were asked to evaluate each of the students they supervised during their final year project against the graduate attributes given in Table 1 and the Likert scale of strongly disagree, disagree, neither disagree nor agree, agree, strongly agree were available for selection. They were then asked to list key strengths and areas that the students needed to improve on. This was completed separately for each student.

A statistical analysis of Likert scale questions was conducted. The responses were scored 1-5 (1 being strongly disagree or poor, 5 being strongly agree or excellent) for each question and averaged. The differences between means were compared and tested for significance using a one-tailed t-test at 0.05 significance (5% confidence level (CL)), using a pooled variance, following the methods presented in Welkowitz, J., Ewen, R. B., & Cohen, J. (2002). The null hypothesis (H0) was that the means of the numerical response were the same between the cohorts, whereas the alternative hypothesis (H1) was that the mean of the responses for 2015-2016 was greater than the mean for 2014 – this implies that the redesign has created a positive effect. Open-ended questions were reviewed to provide qualitative analysis of the data to establish themes in the answers given by the students and staff.

Results and discussion

Student self-evaluation against graduate attributes

The numbers of student responses received were 19 in 2014 (15 completing the survey) from a cohort of 79 students, 6 in 2015 (3 completions) from a cohort of 85, and 23 in 2016 (16 completions) from a cohort of 89. As it is believed that there should be no difference in responses between 2015 and 2016, these results were combined due to the low numbers of responses in 2015. Students evaluated themselves against the graduate attributes shown in Table 1. A summary of the results for the self-evaluation is given in Figure 2.

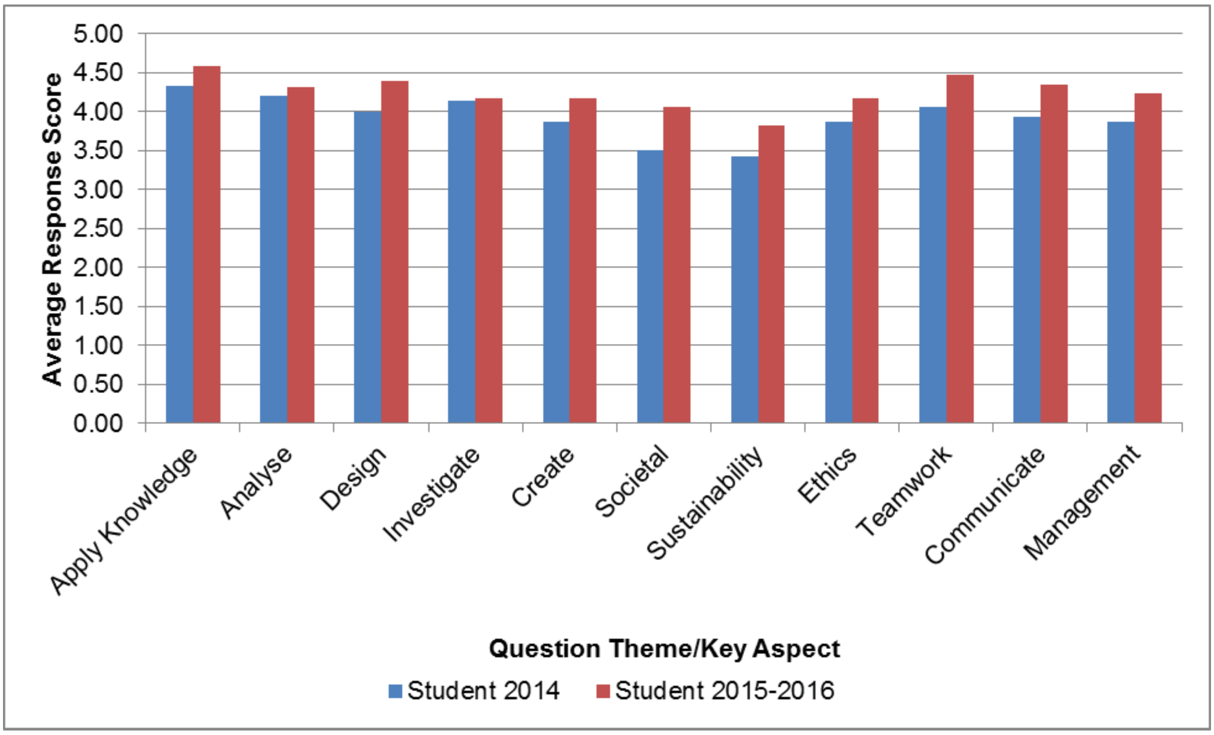

Figure 2 Student self-evaluation against the graduate attributes for BE (Hons)

It is observed that the students completing the redesigned degree from 2015 and 2016 rate themselves more highly against every attribute than the students from 2014. The largest percentage differences were approximately 9-10% for the assessment of Design, Sustainability, Teamwork, Communication and Management and, 15% for Societal attributes. A perception of strong ability in professional skills such as teamwork, communication and management is consistent with the observations of Lima *et al* (2006) when using Project-led education in an engineering programme and with the expected benefits of PBL (Frank *et al*. 2003, Mills and Treagust, 2003, Helle *et al*. 2006).

However statistical analysis of the results showed that there was only significant difference between the means of responses at 5% confidence levels, for the aspects of Design and Societal attributes. That students might be more confident in Design is consistent with the redesigned degree that uses a higher number of projects requiring students to design a solution. Societal attributes are consistent with the emphasis in the redesigned degree around context, sustainability and ethical considerations that are dependent on each other. It might be reasoned that there should be significance for aspects related to “teamwork” and other professional skills’ since ‘design’ occurs in situations that are complex socially (Palmer and Hall, 2011, Dym *et al*, 2005). Yet, although the students in 2015 and 2016 appear to rate themselves more highly, it is not clear that there is a real difference between the cohorts. The variance or spread in mean values of responses was often higher for 2014 and this can lead to a lack of significant difference. The larger variance might occur because the professional skills did not have the same emphasis in the older degree structure and therefore were not as well understood by that cohort.

Staff evaluation of students against graduate attributes

There was an evaluation of 32 students from 2014, 6 from 2015 and 22 from 2016 (combined into one group of 28 for analysis) by academic staff. Staff evaluated students against the graduate attributes shown in Table 1. A summary of the evaluation by staff is given in Figure 3.

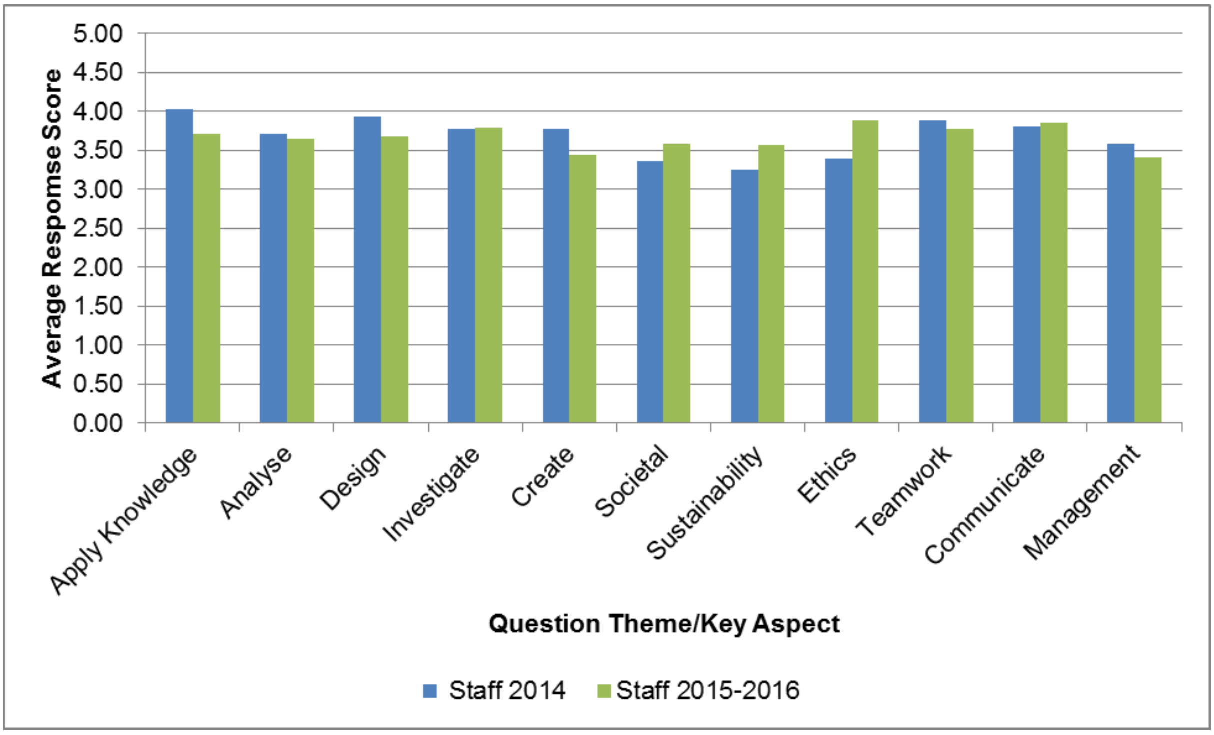

Figure 3 Staff evaluation of the student against the graduate attributes for the BE (Hons)

The staff evaluation of the student's ability against the graduate attributes contrast with the students' self-evaluation. Here the staff rate the 2015-2016 cohorts as less able in some of the attributes – those attributes associated with applying knowledge, analysing, design, creativity, teamwork and management. There is some agreement with the student self-evaluations as they rate the 2015-2016 cohorts more highly with respect to societal, sustainability and ethical attributes. Statistical analysis showed that at the 5% confidence level the only significant difference was around the ethical attributes (i.e. "This student is able to: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.") Whether the staff or students are correct about improvements from the old degree to the redesigned degree cannot really be known. However staff comments for 2015-2016 on "what areas do you feel this student needs to work on?" reveal that the result on "applying knowledge" is seen as an issue. For example, staff made six comments on this theme such as; "Apply knowledge from other courses to projects" and "Applying the principles of science to the problem"

These comments were not made for the 2014 students. Written communication was a common area of improvement for all cohorts (5 comments in 2015-2016 and 8 comments in 2014). The result for teamwork is difficult to gauge as the final year project for individual students has changed between the old and redesigned degree from a design-build-test project to a research project. The redesigned degree introduced a final year team-based design-build-test Capstone project. Staff may not have seen the students working in the team in their final year, but it may also mean that students are compartmentalising learning to a course rather than across their work, which is similar to observations made by staff.

Student Evaluation of the Degree with respect to the graduate attributes

The students of 2015-2016 rated that the redesigned degree prepared them better for every graduate attribute except 'investigation' compared to the 2014 cohort. Table 2 shows the attributes that showed a significant difference in mean scores at 5% CL. Scores ranged from 3.17 to 4.25 (2014) and 3.75 to 4.62 (2015-2016). The average increase in means was between 2% ('create') and 21% ('societal'). 'Investigate' showed a reduction of 2%.

Table 2: Student evaluation of the degree with mean rating

Key Aspect	Cohort Mean Score (1-5_	
	2014	2015-2016
Design	3.67	4.38
Societal	3.17	4.00

For key aspects 'design' and 'societal' the mean value of the response was significantly different at 5% confidence levels. This could be due to a greater awareness of some concepts for the redesigned degree – the students in this degree are exposed to the concepts of societal context, sustainability and teamwork more often than before. The response for 'design' is likely to be an indication of the increased design content using PBL.

Student Evaluation of the Teaching, Assessments, Staff and Overall Experience

The number of students answering these sections of the survey was approximately half of the responding students overall. Only results significant at 5% confidence levels are shown, with the exception of the overall degree rating.

Table 3: Student Evaluation of Degree with Mean Rating for Questions

Question to evaluate	Cohort mean score (1-5)	
Please evaluate the following statements based on your experience throughout your Engineering studies at Massey University.	Student 2014	Student 2015-2016
The balance between lectures and practical exercises was about right	3.46	4.43
The rate of feedback on your assessments was acceptable	3.23	2.14
Overall how would you rate your experience here at Massey	4.50	4.40

Between cohorts there were no differences in how the students rated staff being experts, being approachable and communicating effectively. The results for teaching showed that the students felt there was much better balance between practical work and lectures in the redesigned degree though the quality of the practical work and lectures was similar. Students in 2015-2016 commented that "the amount of practical experience…is much higher at Massey" and "…appreciated the smaller class sizes and practical skills I have learnt". This is in contrast to 2014 where comments were "there not a lot of practical exercises" and "…there were lots of lectures which did not have practical exercise and had only theory…" The main increase in practical work has been through using the project spine in the redesigned degree. This is encouraging, suggesting an improvement in the degree structure. Practical work has been seen to be one of better aspects of PBL (Palmer and Hall, 2011).

Feedback on assessments is clearly an issue in the redesigned degree. Although the quality of feedback was not significantly different, the rate at which feedback was returned was rated much lower by 2015-2016 compared to 2014; similar feedback issues have been observed elsewhere (Palmer and Hall, 2011, Lima *et al.* 2007). Seven out of ten students in 2015-2016 comments on feedback concerned the slow rate of return of feedback and its poor quality.

The overall evaluation of the degree showed that the 2015-2016 cohorts rated their experience and the degree slightly worse than the 2014 cohort but this difference is not statistically significant at 5% CL. It suggests that the redesigned degree has not yet achieved a desired outcome of a degree with greater engagement and appeal for students compared to the old one. As the students of 2015 and 2016 were the first ones through the redesigned programme any implementation difficulties would have been perceived negatively.

Conclusions

Qualitatively, the redesigned BE (Hons) appears to give students more confidence in their ability as Professional Engineers. It is significant that their judgement of professional skills around applying engineering solutions to societal and cultural concerns has improved. Although the trends shown were not significant, it is an indication that the students understand and are more aware of the importance and use of professional skills in terms of ethical, sustainability, teamwork and managerial considerations as well as a greater appreciation of design aspects, which has been shown elsewhere (for example Frank *et al*, 2003). Staff believe some aspects around professional skills have improved but are unchanged or worse in other aspects such as in the application of knowledge. It is also significant that the balance of practical and theoretical aspects of the degree appear to have improved, and improvement in these areas shows that a PBL-based engineering degree is assisting in reducing the gaps between previous graduate attributes and the required graduate attributes. Further surveys of future cohorts will be more targeted with specific questions for areas of improvement.

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Ethics problems that challenge engineering research students

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Abstract

SESSION

C3: Integration of teaching and research in the engineering training process

CONTEXT

Australian PhD students engage in a problem-based learning pedagogy, focussed on a single research question. Not only project-specific details, but also general research-related knowledge, including ethics expectations, is learned within the supervisor-student relationship. The past decade has seen changes to include some formal, lecture-based teaching of more generic material such as ethics. What should be emphasised in this teaching of research ethics?

PURPOSE

The purpose of this work was to see which type of ethical problems would be most challenging for research students, and thus needing of more class-room time.

APPROACH

Research students in their first year of study were provided with one class exploring the general ethics principles under-pinning research integrity. Following this, the students worked in groups to decide whether various actions were ethically appropriate or not. The results of each group's deliberations were collected and examined for feedback purposes. Approximately 400 students were involved over 3 semesters.

RESULTS

The actions were grouped into categories. Students did well with the ethics of the more familiar topics of intellectual property, publications and data integrity. They show some confusion about how projects should or should not impact human participants, but the seriously challenging issues for students centre on conflicts of interest, indicating that this last-named needs extra attention.

CONCLUSIONS

Providing a general introduction to research ethics can ensure students have a balanced awareness of the types of challenges they may face in their future work as researchers. In particular, it is necessary to explore topics that (i) come up less frequently and so may not arise during the PhD research project or (ii) are complex and need wider perspective to better understand.

KEYWORDS

Engineering ethics, ethics education, research training, research integrity

Introduction

This paper explains how engineering research students, when asked to make judgements about a variety ethics problems, found those related to conflicts of interest by far the most difficult to deal with. It argues that formal teaching time be invested to address this problem. The discovery was somewhat serendipitous, coming from some routine student feedback collected after delivering classes about research integrity.

There is a widespread desire that research students learn more about research integrity (see e..g. Steneck & Bulger, 2007). At one level, this is in the hope of reducing cases of research misconduct. There is, though, a more fundamental issue, namely that practising research integrity is needful so that the research enterprise may continue: undertaking research depends on trust between researchers and resourcing it and successfully transferring its results to social benefits depends on public trust. Exactly how this preferred behaviour follows from students learning about research ethics is not immediately obvious. There is, thus, some confusion about the true purpose of such learning and, thereby, the content of ethics education. Is it simply knowledge about research ethics that is needed? Or is it inculcating an ethical approach? At the very least students should become skilled at recognising and discussing ethics problems, a necessary, but not sufficient, precursor to ethics maturity. The first step, then, toward achieving this is to identify the sorts of ethics problems that students find difficult. This is the discovery reported in this paper. It is a question of sociology or human nature why knowledge of research integrity principles is not always put into practice. Behaviour is about choices, albeit ones based on knowledge.

Formal, course-based teaching of engineering ethics has been much examined, particularly at the undergraduate level, where it is becoming more common to find engineering courses in which something about ethical practice is an explicit learning outcome. Debate continues, though, about whether or not these courses work as a way of improving ethical practice. For example, both Anderson et al (2007) and Cech (2014) showed it makes scant difference; in contrast, Borenstein et al (2010) and Skinner & Bushell (2013) claimed some success, at least in developing students' awareness of problems and expectations. When it comes to engineering research students and ethics, though, there is very little published work (and none found directly useful to this study). Nevertheless, it seems reasonable that courses will be equally effective with research students as with undergraduates and this will be assumed for the purposes of this paper. How effective such coursework may be in reducing (research) misconduct is unknowable, even though it is seen to be effective in helping students identify and engage in a shared discussion about these critical issues.

There is, however, much more literature investigating research students in the health disciplines, wherein experiments are much more commonly conducted directly with humans. For example, Schmaling & Blume (2009) and Plemmons et al (2006) both showed that formal instruction improved knowledge but not attitudes, and Heitman et al (2007) and Langlais & Bent (2014, and who also included social scientists) did not examine the effectiveness of course-work so much as pre-existing attitudes and understandings.

Australian PhD students engage in a problem-based learning pedagogy, focussed on a single, unified research project. Not only project-specific details, but also generic research-related knowledge, e.g. ethics, is learnt within the supervisor-student relationship. This means that, unless a topic is germane to the project, it is unlikely to be on the student's learning agenda. The past decade has seen some changes to this practice, with many institutions now including some formal, lecture-based teaching of more generic materials, at least in an induction course. The principles of research integrity are a natural inclusion in such coursework.

As part of a formal induction course at UNSW, engineering research students in their first year of enrolment were provided with a single lecture exploring the general ethics principles under-pinning research practices. Following this lecture, students worked in groups to decide whether or not each of a list of simple actions was ethically appropriate. The results of each group's deliberations were collected and examined for feedback purposes. In total, approximately 400 new research students were involved, over three semesters. By a wide margin, conflicts of interest proved to be the most difficult issues for them to assess. Indeed, the amount of difficulty for these problems, compared with others, was astonishing. The research-teaching nexus is usually about taking research to the 'class-room.' This work suggests that the strengths of class-room teaching should be brought to the learning of research practices.

The next section provides more details about how conflicts of interest were identified as the key problems for students. It is followed by a discussion of the implications for teaching ethics to research students.

The Discovery

This study is concerned with the thinking of higher degree research students during their first year of study at UNSW. The students did the task described below while completing the research induction course GSOE9510.

During this course, the Faculty's new research students receive a one-hour lecture introducing the formal principles under-pinning ethical research. This focusses on research integrity, as defined by the *Singapore Statement on Research Integrity* (World Conf Research Integrity, 2010) and the *Australian Code for the Responsible Conduct of Research* (NHMRC, ARC & UA, 2007). Following this lecture, to reinforce learning, a staff member spends about 20 minutes discussing six simple examples with the students, to determine "what is wrong here." For example,

> *Not informing people the project is sponsored by the military.*

The remainder of the three-hour class involves the students working in self-organised groups of six to eight, seated around a table and facilitated by a tutor. They are given a list of 38 simple actions, each described in a simple statement, e.g.

> *Quoting someone with acknowledgement but without permission.*
>
> *Purchasing lab supplies from a friend's company.*

Students must collectively decide whether or not each action was ethically acceptable. They may also choose 'it depends,' and provide a reason. In practice, less than half of the 'it depends' answers come back with a reason indicating that this answer might be also interpreted as 'don't know' (though blank answers were that). Each table records its decisions on an anonymous worksheet, as a quality assurance measure to allow staff to check what students were thinking. The aim is simply to see how well they translate the theoretical ethics principles to real situations and so to crudely assess the effectiveness of the state of knowledge of the class. To complete their formal education about research integrity, students later complete an online module. After that, it is entirely up to what is learned from the supervisor and other people while prosecuting the research project.

This activity occurred for a total of 3 sessions in 2015 and 2016, when a total of 57 different tables completed anonymous worksheets which were collected and analysed. The result of this fed back into subsequent teaching. With six to eight students per table, approximately 400 students in total will have been involved in this exercise. The exact number is unknown as attendance was imperfectly recorded. Hence, it is also impossible to know the exact make-up of the student population involved. However, the research student cohort as a whole comprises approximately 72% male (28% female) students, 93% PhD (7% research master) students, and 91% full-time (9% part-time) students. There is a wide mix of cultural backgrounds: 21% citizens, 23% permanent residents, 55% international students, and 1% New Zealanders. There is no reason the students involved in this task departed far from that mix. The students are from all engineering disciplines. Proportionately more will be from the larger disciplines (civil and computing), but this is rarely more than 20% of the entire cohort.

For analysis, the 38 questions were grouped into eight different categories: publication and review, human research, handling data (processing and management), intellectual property, conflicts of interest, procedures, supervisor relationship, & safety. These eight groups are convenient for most problems associated with research integrity, but they have no theoretical basis. The questions were presented to students in random order.

The responses from all 57 student tables were tallied for each of the 38 questions, and then the average response was obtained for each question category. Table 1 shows the results. Number of questions is the number in that category. Average unsure is the average fraction of ‘it depends’ answers. The average score requires more explanation. For each question, there is an answer which most (if not all) ethics theorists would support. Call it the Better Choice. It is not always ‘no’ (to keep students alert). Discard the ‘it depends’ answers for a question; subtract the number of Worse Choice answers from the number of Better Choices; normalise this difference. The score is +1 if all committing tables agree with the Better Choice and -1 if all tables disagree.

Table 1: Aggregated student replies for each ethics problem category, ordered by average score.

Ethics focus category	no. of questions	average score	average unsure
Procedures	3	0.96	0.07
Handling data	6	0.86	0.14
Publication & review	8	0.79	0.11
Intellectual property	5	0.72	0.13
Supervisor relationship	2	0.64	0.24
Safety	1	0.48	0.23
Human research	8	0.46	0.22
Conflict of interest	5	***-0.13***	***0.36***

The startling result of Table 1 is how challenging issues in the conflicts of interest category proved to be. Something had to be most difficult, but it is the magnitude by which it comes last that surprises: it is the only category for which the average choice—when a definite choice was made—is a Worse Choice and just over one third of student tables chose ‘it depends’ (or were unsure). When compared to other categories, the degree of this difficulty is so large that, despite not being designed as a rigorous piece of research, this is worth reporting.

Human research ethics proved second most difficult. This is less surprising because most new research students will have had very little formal experience of research with humans. Indeed, most will never need to learn about this during their project work either, and it suggests a gap in the training of young researchers that needs filling by such class-room activities.

The safety score is interesting. Why is it so low? This single question was included to see the response, as a form of calibration. Maybe its answer is the cavalier attitude of youth, or maybe an expression of the perversity when confronted with a ‘trivially obvious’ question. Or maybe something else altogether. A more rigorous piece of research is needed to explore this further.

You can see that the students did reasonably well with the ethics associated with the other categories, including publications and data integrity.

The categories of ethics problems in Table 1 are somewhat arbitrary; problems could be grouped otherwise. However, references were scanned to see whether any theme had been ignored. The categories here compare favourably with the chapters in the Australian guide (NHMRC, ARC & UA, 2007)—management of data, supervisor/trainee relationship, publication, authorship, review, conflicts of interest, collaboration, and breaches process—and the chapters in Steneck (2007)—protecting humans, protecting animals, conflicts of interest, data management, mentor/trainee relations, collaborative relations, authorship, peer review, and misconduct processes. Thus, we believe that they are adequate to cover the range of problems engineering students need to cover in their education as researchers and there do not appear to be gaps that need adding to the limited class-time and missed by these recommendations. Note that animal research was not considered as a relevant category in this paper.

Given the differences in methodology, it is difficult to compare the results here with others. However, it is worth noting that the large survey of commencing biomedical students by Heitman et al (2007) had conflict of interest at the bottom of issues with data management matters at the top, and they were also concerned by relatively poor scores on conducting human or animal research, given their focus on experimenters on people or animals. Similarly, Langlais & Bent (2014) found conflict of interest to be worse understood than data management and publication ethics.

Discussion and conclusion

Providing generic teaching of ethics can ensure students have a balanced awareness of the sorts of challenges they may confront in their future work as researchers. However, three hours of formal learning is insufficient to cover all the nuances of research integrity, so those ethics problems needing most urgent attention must be identified. As a first step, this paper shows that conflicts of interest are the class of problems that our engineering research students found most difficult. Changes have been made to the one-hour introductory lecture, to better explain and illustrate the ethics associated with conflicts of interest. First results from 2017 have shown an improvement, but this remains a work in progress.

Anecdotally, some supervisors don't appear to understand conflicts of interest very well either. Certainly the highest levels of leadership of our society provide plenty of examples of conflicts of interest not being identified, not challenged, and thus indulged. Given this example, perhaps we should not wonder at their being the most difficult challenge for students. Also, the aggregated nature of student responses used in this paper meant that no information became available about whether or not any particular sub-group (e.g. cultural backgrounds) may find these problems more confusing than others do. Heitman et al (2007) surveyed individual students to show that this was the case.

It is reassuring that students performed relatively well with topics typically explored from the earliest years of their engineering education, issues such as respect for intellectual property (and avoiding plagiarism) and keeping trustworthy experimental records. This is particularly pleasing given the diverse educational backgrounds of these students.

We conclude that there is a need to cover generic aspects of human research in greater details in the common coursework requirement. This is for completeness. Most students will not need to submit an application to a human or animal research ethics committee during the course of their respective degrees, and so will not learn more about the relevant principles from conducting the project. This missing of a key component is an inevitable risk of relying entirely on a problem-based learning pedagogy.

Ethics values form part of a researcher's identity. Just as parents generally have the strongest influence on an individual's inter-personal ethics, the strongest influence on a student is observing the behaviour of the supervisor and other established researchers, which is intuitive but has also been demonstrated (e.g., Anderson et al, 2014). Coursework will never have an impact to match that. We are all familiar with how work-places disparage the achievements of students in the academic context of universities and this badly affects students' attitudes to study. Learning about ethics in a teaching context will be worthless if the supervisory team downplays its worth. Nevertheless, effective instruction is able to awaken awareness of ethics problems. This paper argues for those topics which need the more urgent attention in the coursework provided for research students.

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Deviating from traditional lectures: Engineering students' perception of active learning

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SESSION

C1: Integration of theory and practice in the learning and teaching

CONTEXT As an early career academic, I was asked to teach one of the modules (out of four) in a postgraduate Engineering course. I took this as an opportunity to redesign the module to tackle one of the main issues in the previous years: lack of student engagement. My redesign included principles of constructive alignment. I developed new learning outcomes and introduced two activities to promote student engagement in the classroom. The class size was small, a total of 19 students, the majority of whom were international. Two types of activities were included: (a) a class discussion and (b) a formative assessment, a quiz to test students' basic knowledge of the lecture material. In this paper, I analyse the feedback from the students and share my own experience. I provide a pathway for other early career academics who are looking to make similar changes to their courses.

PURPOSE The purpose of this study is to describe the pedagogical changes and show their effects through data on students' perceived learning of the lecture material.

APPROACH A survey was undertaken pre- and post- completion of the module. The questions included in the pre-completion survey were on students' previous experience of the subject, and their preference for lectures taught in the traditional transmissive model or with class activities during the lecture. The second survey included questions on their perceived knowledge of the subject and if they found the quiz and in-class discussion helpful in assisting them to achieve the learning outcomes.

RESULTS All students, except one, stated that they felt more confident to work in a job involving public transport after the completion of the module. Thirteen students (out of the 16 students who completed both surveys) indicated that they found both activities useful for their learning. Around 6 students out of 16 initially indicated that they prefer lecture only classes and later indicated that they found the in-class activities to be helpful in their learning. The main reasons why the students found the quiz helpful was because it gave them an opportunity to review the lecture material and be proactive in their study. As for the in-class discussions, the main reasons students found it useful was because they could engage with the material, hear the opinions of their peers and express their own views.

CONCLUSIONS Overall, the feedback from the students showed the usefulness of the constructive alignment concept when creating new lecture material. The learning outcomes were connected to the two in-class exercises and this produced a positive feedback from the students. The findings of this study showed that the theory of constructive alignment can help scope what to include in the lecture material and how it can be taught. I would like to encourage early career academics to try innovative approaches in their teaching.

KEYWORDS Early career academic, constructive alignment, student engagement

Introduction

A new staff member often finds themselves included in a course designed by someone else and asked to either modify or create new lecture materials. This can be a nerve-racking task, as not only do you need to define the scope of the material to be taught but also to determine how it will be taught. Making a mark as an innovative teacher may be difficult when the original course authors are still involved in the course. These co-teachers are more likely to be higher in the institutional hierarchy and well-established within it, while the new staff is typically an early career academic. I argue that in such a challenging situation, early career academics can perceive it as an opportunity to try an innovative approach to their teaching. The life of a student is still fresh in the minds of an early career academic. They remember what it is like to sit in lectures that are not engaging and become disconnected from the content being taught.

There are many methods of teaching and each discipline has its own traditional way, often influenced by expectations on career trajectories. For example, Engineering produces a body of professionals who are required to possess certain trade skills and to be aware of the code of ethics for their practice after graduation. Yet despite the need for practical competence, most courses are taught with the teacher transmitting knowledge. As such, students expect lecture times to be where they take notes while being taught about the course materials. Despite the growing evidence of active learning in Engineering courses, many courses are still taught in the traditional transmissive model (Freeman et al. 2013). As such, deviating from this form of teaching takes courage. Activities outside of class times are undertaken mostly in groups or pairs, and Engineering students are accustomed to working in groups outside the class. So, what approach might an early career lecturer take to bring this level of enthusiasm for learning into the classroom?

As an early career academic, I was asked to take one of the four modules in a postgraduate course. In the previous year, I sat as an observer to the course. I noticed that many students quickly became disengaged from the teaching and this lack of interest continued throughout the day. Here, let me explain that most Masters degree courses in Engineering in my institution are taken in blocks. In each block, students are taught from 9am to 5pm for 2-3 days. A semester will typically have three blocks for one course. These courses commonly have around 20 students. Therefore, when I was asked to be part of this course, I decided to re-design the module I will be teaching to include more student engagement during the lecture. I adopted Biggs theory on constructive alignment. Most of the Engineering courses do not have constructive alignment, so adopting this concept is my contribution to the course. For this theory, Biggs (1996) emphasises that pedagogy is strongest when it is the learner who is central, not the teacher as the transmitter of knowledge. The learner accumulates knowledge by actively selecting and constructing their knowledge through individual learning and social activity.

Given that the class size is small, I decided to include two activities which required participation from everyone. The present study looks at the effects of these changes on the students' perceived learning. This paper discusses students' perceptions of: (a) whether the activities helped them achieve the learning outcomes and (b) their perceived learning given the inclusion of activities which required their engagement in class. Pre- and post- surveys were undertaken for the module I taught to determine these two research objectives. The next section provides a summary of relevant published articles.

Literature review

Biggs (1996) suggests that when selecting different types of teaching/learning activities, it is important to bear in mind that lecturers do not need to be the sole source of knowledge. Peer learning is a great alternative as it allows the students to hear different options. Exercises undertaken in the classroom from now on will be referred to as active learning, promote engagement and peer learning. They differ to the traditional lectures, in which students primarily listen and take notes. Active learning, particularly problem-based activities, allows the students to achieve *deep learning* instead of *surface learning* (Marton and Salijo 1976). The traditional transmissive model tends to entail surface learning. In deep learning, students think critically about the information they are given and apply that thinking to a task, while, in surface learning, students focus on memorizing the information (Wang et al. 2013). Teachers who intend to promote *deep learning* require the student to actively process and apply information in a variety of forms. Lectures including active learning within the classroom, for example, by using quizzes, group discussion and problem-solving exercise, were shown to improve students' test scores and reduce failure rates (Wieman 2014). Hartley and Davies (1978) suggested that breaking up the lecture time helps to keep students engaged. Students are shown to remember 70% of the first 10 minutes and 20% of the last 10 minutes. In-class activities give students some time to absorb the material being taught, while also giving them a break from listening and this helps them retain the knowledge for a longer period.

Prince (2004) discussed the types of active learning exercises that have been incorporated into Engineering courses. The main distinguishing feature between active learning exercises and a take-home assignment is that they are completed in the classroom at lecture times. There are three kinds: (a) collaborative learning, (b) cooperative learning and (c) problem-based learning. Collaborative learning includes small groups of students working together while cooperative learning includes a small group of students in which each are individually assessed (Bruffee 1995). In Engineering, cooperative learning and problem-based learning are the most common. The study highlights that the results from problem-based learning varies and that in some cases the improvement is marginal. To produce deep understanding, they need to be designed around learning outcomes and promote engagement from the students (Wiggins and McTighe 1998, Forbes et al. 2001). Active learning has been seen to have the highest impact on courses with 50 or fewer students and was shown to have a positive effect on learning, evidenced by reduced failure rates (Freeman et al. 2013).

Feedback to students during the course is an important tool to aid in their learning. However, providing feedback to students has been identified as one of the weakest aspects in higher education teaching. A solution to improving this weakness is to conduct formative assessments. Such assessments are used to provide feedback, both to the lecturer (on how much the students know the material) and to the students (how much they have learned and what is expected of them) (Dixson and Worrell 2016). Formative assessments are also known as "early-warning summative" assessments and "assessments *for* learning". They can be included during class times to engage students with the lecture material and keep learners' minds in the classroom during teaching (Dibu-Ojerinda 2006). Formative assessments challenge the learner to think deeply about the content and discourage surface learning. How the feedback is provided has an effect on the students' learning. If feedback is transmitted to the students on the right and wrong elements of their academic work, then students can become empowered to develop self-regulation skills. Such skills are required in the profession, particularly in Engineering, where you are made accountable for any mistakes. Nicol and Macfarlane-Dick (2007) discussed the seven principles of good feedback. One of them is to encourage the teacher-student dialogue around learning. Teacher needs to clarify what is the standard performance and how students can close the gap between current and desired performance.

A fundamental question across the science, technology, engineering and mathematics (STEM) disciplines is whether we should ask or we should tell (Freeman et al. 2013). Many STEM courses (Freeman et al. 2013) have been including active learning in one form or another. However, lecturers commonly worry that not as much material can be covered by deviating from the traditional model. Buck (2016) states, in defence of the traditional transmissive model, that a skilled lecturer can present the material so effectively that the material seems clear, even to the most naïve listener. However, is this full mastery of the material? Without a chance to apply the content, is the student truly able to achieve mastery in their learning? Graduates are expected to have full mastery of their subject area. They are perceived by the industry personnel to be the ones who bring fresh and exciting knowledge with them from the university. As such, mastery of the subject area is important not only for their employability but also for their career growth. As lecturers, it is our duty to ensure that students had the opportunity to practice the concepts. Simply providing lecture notes cannot be expected to produce full mastery of the subject. Active learning exercises can assist with this issue by allowing the students to apply the content in class under the support of their peers and the lecturer. By *asking* questions instead of *telling* about the material can be an effective way to teach. It provides students with an opportunity to engage their minds. This ends up allowing the students take ownership of their learning which will inenviably lead to better understanding of the subject (Stegemann and Sutton-Brady 2013).

Description of the module's re-design

Development of learning outcomes

Setting goals at the beginning of class can provide clarity on what is expected from the students (Martin 2006). It also provides for the instructor a way to focus the teaching material. One way of setting these goals is to develop learning outcomes. Learning outcomes inform students about what they are expected to know from a course or module. Once they are set, the course content can be delivered by creating teaching/learning activities which will help the students to achieve the learning outcomes. Assessments can be used to test if the learning outcomes have been met. This concept is known as "constructive alignment", developed by John Biggs in the 1996 (Wang et al. 2013). Constructive alignment is a useful tool for teaching, particularly for early career academics. The concept helps create a road map when creating new lecture materials and assessments.

Bloom's taxonomy (Adams 2015) was used to develop the new learning outcomes of the teaching material for the module I was teaching. These learning outcomes were presented at the beginning of the lecture notes. Bloom provides a list of verbs and the relative effort required to achieve them by the learner (Stegemann and Sutton-Brady 2013). For example, the verb "*summarise*" places the expectation on the student to memorize and repeat the concept, whereas the term "*analyse*" requires the learner to draw a connection among the ideas taught and apply them to a problem. In formulating the outcomes, typical questions the teacher can ask themselves are "*What do I want my students to be able to do?*" and "*What do I want my students to appreciate/ value?*". Following these questions, the new learning outcomes I developed are given in Table 1, with the verb for each learning outcome emphasised. The table shows that several levels of mastery (summarise, understand, create, analyse) of the subject area are expected from the students.

Table 1: Learning outcomes for new module

Learning outcome 1	***Summarise*** the important concepts in Integrated Public Transport system's operation.
Learning outcome 2	***Understand*** the psychological and statistical models used for travel behaviour.
Learning outcome 3	***Create*** data collection procedures for travel behaviour models.
Learning outcome 4	***Analyse*** current issues related to transport and the future of public transport.

The learning outcomes were also aligned with two attributes stated in the Postgraduate Coursework Graduate of the university:

(a) **Specialist knowledge**: An understanding and appreciation of current issues and debates in the field of study [first and second learning outcome];

(b) **General intellectual skills and capacities**: An ability to analyse information, where appropriate, using appropriate tools, technologies, and methods [third and fourth learning outcome].

Development of the active learning exercises

The goal of higher education is to produce individuals who are confident and independent learners to "sustain a learning society" (Taras 2010). The National Association of Colleges and Employers (2016) conducted a survey and found the top attributes desired in new university graduates. Table 2 shows the top five attributes. Team work and communications skills are among these top five attributes.

Table 2: Attributes employers want to see in new graduates

Attribute	Percentage of Respondents
Leadership	80.1%
Ability to work in a team	78.9%
Communication skills (written)	70.2%
Problem-solving skills	70.2%
Communication skills (verbal)	68.9%

The course had 19 students, 14 of whom were international students (those who did not complete their undergraduate degree in the country). This dynamic was considered when developing the activities to engage students. A key motivation for the international students to undertake a Masters degree is to find a job in the industry. As such, I developed class activities which will give students an opportunity to work in a team and practice their communications skills, both written and verbal.

One of the activities was a class discussion. The students had an opportunity to engage in a group discussion about a specific topic. The discussion was supplemented with recent magazine articles on the topic. After the students discussed for approximately 30 minutes, a member was selected to report back to the class. The purpose of this exercise was to allow the students to express their own views and to learn from their peers. This activity helped the students to achieve Learning outcome 4. In the Engineering profession, it is a common practice to have group discussions and this in-class activity gave the international students an opportunity to practice their verbal communication skills. While I was planning this activity, I was apprehensive about its success. This is because most international students are accustomed to the traditional transmissive model of learning (Kember 2000). The class discussion was very successful; everyone in the class engaged and expressed enthusiasm. Given its success, for the next class I designed the class notes to have gaps. These gaps were filled by mini class discussions throughout the lecture.

The second activity comprised of an in-class quiz, worth 5% of the total grade. The questions in the quiz were designed to help the students meet the first two learning outcomes given in Table 1. They are:

- Summarise the important concepts in Integrated Public Transport system's operation.
- Understand psychological and statistical models used for travel behaviour.

Assessments can be an effective way of assisting students' learning through motivation. Formative assessments are an important component of teaching as students require accurate self-assessments to guide their learning process (Marchand and Furrer 2014). As such, when formative assessment are properly aligned with learning outcomes, the feedback can be used to help the students achieve them (Wanous et al. 2009). The weight of the assessment was kept at the lower end as the purpose of this activity was for students to receive feedback on their learning.

The quiz was a mixture of multiple choice and short questions. The short questions helped the international students practice their written communication skills. It is expected that the feedback will help the students know the gaps in their understanding of the lecture material and allow them to prepare for the final examination that is worth 50% of the total grade.

Data collection

The data was collected using pre- and post- surveys of teaching the module. This research method has the advantage of allowing the lecturer to assess the effects of their teaching. One of the disadvantages is that a control group was not allocated. Given the small class size, everyone was invited to participate in the survey. The students were handed an envelope with a number. The number was unknown to me to keep the surveys anonymous. This helped the students feel comfortable to express their authentic views in the surveys. Each envelope contained two survey forms and a participant information sheet (PIS). The survey forms had the same number as the envelope's number. This allowed the survey forms to be tracked and compared for analysis. The PIS outlined the objective of the study and informed students that the surveys have been approved by the university's Ethics Committee. Students were also informed that participation is voluntary and that they could opt out at any point. The survey forms were completed and collected during class time. All students returned the questionnaires in a box to preserve anonymity. Table 3 provides the items in the questionnaires and the response options.

Table 3: Items in questionnaires

	Question	Response options
Survey 1		
Item 1	Does your current job involve any work on public transport? If "yes", please rate from 1 (poor) to 10 (very good) your confidence in working on public transport systems.	Rate 1 (poor) to 10 (very good)
Item 2	Did you complete your bachelor degree in New Zealand?	Yes/No
Item 3	What kind of class interaction do you prefer?	Lecturer provides notes only/In-class activities along with lectures
Survey 2		
Item 4 (links with Item 1)	Do you feel more confident about working in a job involving public transport?	Rate 1 (poor) to 10 (very good)
Item 5	Did the quiz help you to achieve at least one of the learning outcomes?	Yes(explain)/No(explain)
Item 6	Did the class discussion help you achieve at least one of the learning outcomes?	Yes(explain)/No(explain)

Results and discussion

Out of 19 students, 16 completed both pre- and post- surveys. Figure 1 shows a comparison of the students' personal rating of their knowledge, on the subject area (public transport systems), before and after the completion of the module. The rating choice given to the students was 1 is poor and 10 is very good.

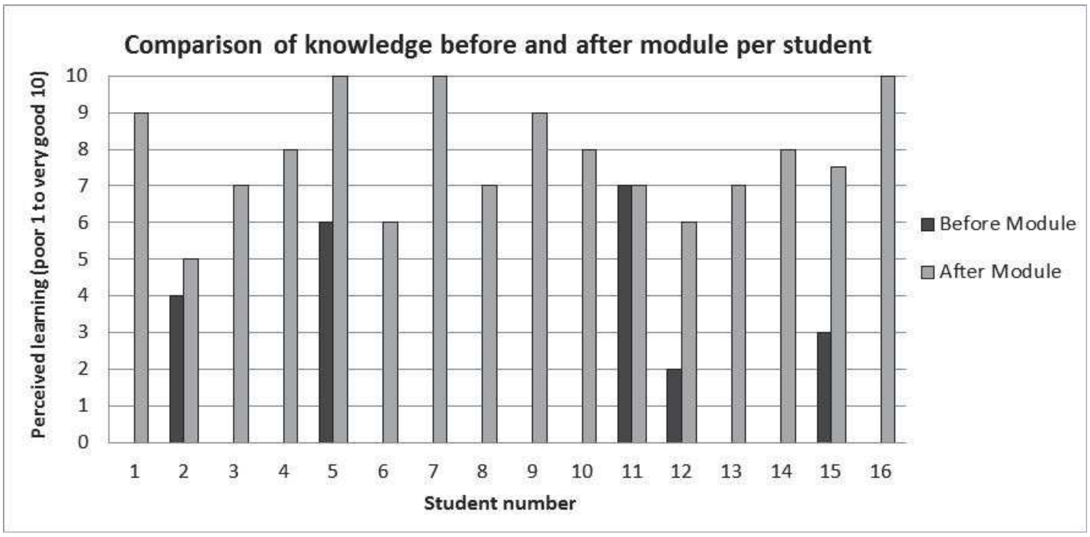

Figure 1: Comparison among students' knowledge before and after module completion

From the 16 students, two rated themselves 6 and 7 for Item 1 (current job involves public transport), three rated themselves between 0 and 4 and the rest responded "no" to the question. Out of the 16 students, 13 were international (those who did not complete their undergraduate degree in the country). The course commonly attracts many international students. Those who are domestic students usually work in the transport industry. Out of the five students who had knowledge of the topic prior to the lectures, three were domestic students. Figure 1 illustrates that majority of the students perceived that they have gained sufficient knowledge on the topic after the completion of the module. The increase is particularly significant for those who did not have any prior knowledge on the topic. The rating increased for all the students except for Student Number 11. This student perceived that they did not learn anything from completing the module. In Survey 2, under "other comments", this student commented that they did not feel anything new was taught in the module. The student felt that the material was too basic and they wanted more advanced knowledge to be taught.

Table 4 provides a summary of the responses from students for Item 3 from the pre-completion survey (Survey 1) and items 5 and 6 from the post-completion survey (Survey 2). For Item 3 (preference for lecture only classes or in-class activities), six students indicated that they preferred lectures only, while majority of the students (10) preferred lectures with in-class activities. Two of the students who said "yes (Y)" in Survey 1 to in-class activities, stated that they did not find either the quiz helpful or the class discussion helpful. Student Number 2 wrote in the survey that the main class discussion was only about one topic. Student Number 10 stated that they did not find the quiz helpful for their learning.

Majority of the students liked the in-class activities. 8 out of the 16 students stated in Survey 1 that they prefer class activities over lecture only classes and they also agreed that they found the quiz and class discussion useful exercises in helping them achieve the learning outcomes. More interestingly, 6 out of the 16 students stated in Survey 1 that they prefer lecture only classes and in Survey 2 agreed to finding the quiz and class discussion useful in their learning. The main reasons why the students found the quiz helpful was that it gave them an opportunity to review the lecture material and be proactive in their study. The quiz also allowed them to understand the key points of the material.

Table 4: Summary of responses from the students

	PRE-MODULE SURVEY (Survey 1)		POST MODULE SURVEY (Survey 2)	
Student Number	**Prefer in-class activity**	**Prefer lectures only**	**Found quiz helpful**	**Found class discussion helpful**
1	Y	N	Y	Y
2	Y	N	Y	N
3	Y	N	Y	Y
4	N	Y	Y	Y
5	Y	N	Y	Y
6	N	Y	Y	Y
7	Y	N	Y	Y
8	N	Y	Y	Y
9	Y	N	Y	Y
10	Y	N	N	Y
11	N	Y	Y	Y
12	N	Y	Y	Y
13	Y	N	Y	Y
14	Y	N	Y	Y
15	Y	N	Y	Y
16	N	Y	Y	Y

From the comments made by the students in Survey 2, it was clear that the quiz helped the students achieve Learning Outcome 1 which is “Summarise the important concepts in Integrated Public Transport system’s operation” more than Learning Outcome 2 “Understand psychological and statistical models used for travel behaviour”. This result is logical as most of the questions in the quiz where short-answer questions which targeted Learning Outcome 1 more than 2. As for the in-class discussions, the main reasons students found it useful was because they could engage with the material, hear the opinions of their peers and express their own views.

Overall, the feedback from the students showed the usefulness of the constructive alignment concept when creating new lecture material. The learning outcomes were connected to the student engagement activity and the formative assessment; this produced an overall positive feedback from the students.

Conclusion

One of our main responsibilities as new staff members is to become involved in existing courses. This task at first feels daunting. There are expectations on how the course should be taught, as it was previously done by senior academics. Sometimes we receive previous lecture notes that have been taught for years and other times we are required to create completely new lecture materials. As a new staff member, I was asked to take one of the four modules of an Engineering postgraduate course. I took this responsibility as an opportunity to deviate from the traditional transmissive model and adopted the concept of constructive alignment. In this paper, I described the changes made in the redesigned module. I developed four new learning outcomes and included two main in-class activities (a quiz and a class discussion) to promote student engagement and assist the students in achieving the learning outcomes. To evaluate the changes, I conducted pre- and post- module completion surveys. This was a small class consisting of 19 students, with 16 completing both surveys.

Overall, the feedback from the students was very positive. The result which stood out for me the most was when 6 students in the pre-completion survey stated that they prefer lecture only classes and in the post-completion survey agreed to finding the quiz and class discussion useful in their learning. They found that studying for the quiz gave them an opportunity to review the material and the class discussion allowed them to hear the opinions of their peers as well express their own views. This is the type of assistance we want to provide for our students. As many of the students were international, the two activities also gave them an opportunity to practice their communication skills (written and verbal). In conclusion, the redesign of the module was successful. I would encourage new staff members to try innovative approaches to their teaching. It may feel like a risk, given the high importance placed on student evaluations, especially for those on a tenure track. However, I found that taking the risk is well worth it and can be successful if we take the time to carefully design the tasks. Students appreciate new approaches to teaching.

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We Built It and They Came: An Adaptive eLearning Experience

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SESSION Integration of teaching and research in the engineering training process

CONTEXT Large classes, students with diverse educational and cultural backgrounds and a time poor society are just some of the pressures educators are faced with today. Added to this is a need to provide students with different opportunities in which to learn. Furthermore, in this 24/7 switched-on world, students expect to be able to learn at a time and place other than in a classroom. It was with this in mind that the concept of a weekly Smart Quiz was integrated into a Petroleum Engineering face-to-face course, providing students with an opportunity to test their knowledge in a low risk, stress free environment. Additionally, it provided students and educators with an opportunity to identify and tackle misconceptions sooner, rather than later.

PURPOSE Research was carried out in order to assess whether given a choice, students would engage with and make use of the Smart Quiz. In addition, evaluating students' perception of learning online, and their attitude towards instant, adaptive feedback took place.

APPROACH In order to carry out this research Smart Sparrow's Adaptive eLearning Platform was utilised. The platform is an instructional content and design tool usually used to create adaptive tutorials. However, in this study it was used to create Smart Quizzes. The major difference between these Smart Quizzes and traditional ones is the instant, adaptive feedback generated as students interact with the activities and questions provided. The Smart Quiz was launched after students had attended face-to-face lectures and tutorials where the various topics were taught and discussed.

Data was collected via a participant's online questionnaire in order to gain insight into students' attitudes and perceptions. The questionnaire consisted of questions in the form of a five point Likert scale, as well as open ended questions. Furthermore, data from the analytics engine in the platform was used to gather information relating to student usage of the Smart Quizzes.

RESULTS Students were overwhelmingly accepting of the Smart Quiz concept, with the vast majority of the class accessing them. This included students across the academic spectrum. In addition, 89.3% of students agreed or strongly agreed that the feedback generated was helpful. In regards to identifying their preferred feedback style, they reported the 'try again' feedback that included a hint, extremely helpful.

CONCLUSIONS In conclusion, students were extremely accepting of the Smart Quiz concept. Without external incentives, students eagerly took control of their learning, making use of the Quizzes in order to support their learning. The ability to access the Smart Quizzes when they wanted, where they wanted and being able to work through them at a pace that suited them was not only evident by the responses provided in the questionnaire, but in the data captured from the analytics engine.

KEYWORDS feedback, adaptive learning, blended learning.

Introduction

Students and educators are constantly faced with time pressures. In addition, they are faced with the complexities which large and diverse classes pose (Baik, Naylor, & Arkoudis, 2015; Tisdell, 2017). Added to this, is the pressure educators are under to provide students with engaging, personalised learning opportunities. From a student's perspective, the need to juggle studies with work commitments has led to an expectation of more flexible learning environments (French & Kennedy, 2017). The advancement of technology has provided educators with a means to adapt the way they teach and the opportunities they provide for their students.

Learning takes time and effort and requires a variety of learning opportunities. There is no one-size-fits-all solution, particularly as students' needs and abilities differ. Papert (1993) proposes that for learning to take place, students need to be actively engaged in the process. In addition, they need to be able to take charge of their learning. Furthermore, Kirschner, Sweller, and Clark (2006), have shown that novice learners benefit from explicitly guided tasks and activities. Added to this knowledge, is the importance feedback plays in learning (Hattie, 2015; Narciss, 2013; Shute, 2008). When classes are large and diverse, however, this is not always easily accomplished.

Online resources involve major in-depth planning. They take time and effort to create. It is therefore beneficial to gain insight into students' attitudes towards such resources. Additionally, it is useful to understand whether there is a particular type of student who would voluntarily make use of them. If online resources are to be embraced by students, evidence is needed regarding potential benefits they may offer; with a specific focus on the role feedback may play.

We describe a real-world study carried out in a 3rd year petroleum engineering course that integrated online adaptive quizzes into a regular face-to-face course. The specific questions considered were:

1. Given a choice, would students voluntarily engage with Smart Quizzes as a way of supporting their learning that could lead to improved subject confidence and understanding?
2. Would students' perceive the inclusion of instant, adaptive feedback to be beneficial and would they have a preference to the type and structure of the feedback?
3. Would educators be able to effectively guide and support students' understanding of complex content from afar?

Background

Students enrolled in a Petroleum Engineering course attended a two hour face-to-face lecture once a week as well as a one hour smaller face-to-face tutorial group. The tutorial occurred prior to the lecture, where students were provided with a question they were required to solve in groups facilitated by tutors. The lecture that followed the tutorial concentrated on advanced and complex areas of the topic. At set times in the course, students completed assessments and/or examinations where they received summative feedback on their progress. One of the aims of the course was to introduce students to background knowledge in numerical reservoir simulations whilst guiding them in how to solve engineering problems. The lecturer involved in the course recognized a need to provide students with learning opportunities that would enable students to rehearse, recall, reinforce and review their knowledge, despite the large and diverse class. He also wanted to provide his students with a safe environment where they could learn without fear of failure (Hattie & Yates, 2013). Thus, in order to provide students with an additional learning opportunity, it was decided to create a weekly online quiz with the aim of supporting and guiding students from afar. We were also interested in whether the quizzes would be used by students, if they didn't count towards their course grades.

The proposed quiz was to take the form of an adaptive quiz that included instant feedback, and was referred to as a Smart Quiz (SQ). The aim of the quiz was to provide students with a flexible opportunity to practice and test their understanding in a low-risk, stress-free environment, that also allowed them to learn from their errors (Hattie & Yates, 2013). It was decided that the resources would not simply digitize lecture notes, but rather aim to provide students with a more personalised interactive and engaging learning opportunity. Moreover, students could learn at a time, place and pace that suited them.

The SQs created, were based on the structure of adaptive tutorials created on Smart Sparrow's™ Adaptive eLearning Platform (AeLP). The AeLP is a web-based, instructional design and content authoring tool enabling educators to create interactive, and adaptive online resources that included the ability to generate instant, adaptive feedback. This platform was selected as it enables educators to maintain their pedagogical ownership of the resources created. It also does not require any specific programming skills. Furthermore, it enables educators to gain 'inside information' on their students use of the resource via the analytics engine (Ben-Naim, Velan, Marcus, & Bain, 2010; Marcus, Ben-Naim, & Bain, 2011).

Quizzes traditionally provide students with summative feedback. However, as this resource was specifically aimed at guiding and supporting learning and not being used purely as a testing resource, it was decided to use formative feedback, allowing the feedback to become part of the learning process. Different feedback types were used, depending on the level and complexity of the question. At the very least, feedback messages included verification such as 'knowledge of response', which identified an answer as being correct or incorrect. Elaborated feedback was used where questions were deemed to be more complex. Feedback included 'knowledge of response' with an explanation (Kulhavy & Stock, 1989; Mason & Bruning, 2001; Narciss, 2013).

Method

Material

The SQs were created using Smart Sparrow's™ Adaptive eLearning Platform (AeLP). The inclusion of instant, adaptive feedback which adapts to students' interactions is a major difference between the Smart Quizzes in this study compared with traditional style quizzes. The first quiz was implemented in week 7 of Semester 2, 2016 followed by a second quiz a week later. The quizzes were uploaded to the course LMS, launching in the relevant weeks and remaining open a further three weeks leading up to the examination period.

Structure of SQs

The SQs consisted of between six and eight questions, with each question or activity linked to relevant adaptive feedback. All questions and feedback were developed by the course lecturer.

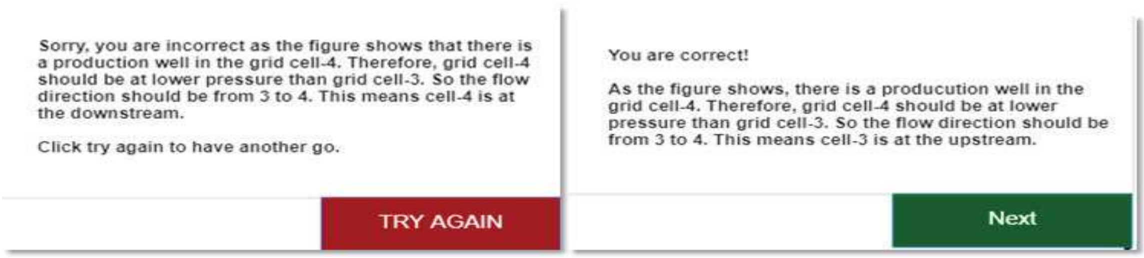

Figure 1: Examples of incorrect and correct feedback messages

A variety of feedback styles were utilised, depending on the type and complexity of the question. Most of the feedback messages included verification as well as elaborate feedback that consisted of a hint or further information (Kulhavy & Stock, 1989). At the most basic level, the feedback reflected 'knowledge of response', indicating to the student that their answer was correct, or incorrect. If an answer was incorrect, students were provided with 'multiple try' feedback. This was 'knowledge of response' with a hint or guidance as to what they may have missed, or what they needed to consider in order to be given another opportunity to answer the question. If they were still unable to answer the question, they were either directed to their notes, or other resources, or they were provided with an explanation that took the form of a worked example and were able to continue with the SQ and their learning process. Where students answered a question correctly, they received 'knowledge of correct response' feedback. This included verification that the answer was correct, as well as an explanation of the correct answer. This explanation was provided so that students who may have guessed the answer, or who may not have been completely sure of their answer, could benefit.

The three attempts 'multiple try' feedback method was specifically selected for use, rather than 'answer-until-correct' feedback style in order to prevent students from becoming frustrated or finding themselves caught in a loop if unable to answer a question. This in itself could possibly add to a students' unnecessary cognitive overload.

There were no time restrictions and students where not restricted by the number of times they utilised the quiz. This enabled student to take control of their learning, allowing them to identify when, where and how they chose to best make use of the resource. Although there were no assessment marks associated with the quizzes, game points were embedded into the various questions and activities, allowing students to see how they fared. These points were included as a motivational factor and were summative in nature.

Data

To gain insight into the students' learning experience, attitudes and perceptions, data was collected via a participant's online questionnaire. The questionnaire consisted of five point Likert scale type questions, as well as open ended questions regarding students' likes and dislikes. Furthermore, data from the analytics engine was extracted, relating to the students' use and interaction with the Smart Quizzes.

Data gained from the analytics engine could highlight particular areas where students may have experienced misconceptions, allowing educators to adapt their teaching accordingly.

Results

This study consisted of both Australian and international students in a first year petroleum engineering course. Student's responses indicated that 43% (n=48) came from English speaking backgrounds, with 57% (n=64) of students coming from a variety of non-English speaking backgrounds. Of the 113 students enrolled in the course, 107 students responded to the question relating to gender, with 62% (n=66) of students identifying as male and 38% (n=41) of students identifying as female.

Given a choice, would students voluntarily engage with Smart Quizzes as a way of supporting their learning, that could lead to improved subject confidence and understanding?

In order to assess whether there was a particular academic type of student who elected to access the SQs, the university weighted average mean (WAM) score of participants were analysed. WAMs are generated by the university based on all the courses a student has completed. Results from the analysis of the 74 participants involved, indicated that students across the academic range elected to make use of the SQs, with the largest group 38%

(n=28) made up of ‘Credit’ students, followed by 31% (n=23) ‘Distinction’ and 22% (n=16) ‘Pass’ students.

Students overwhelmingly embraced the Smart Quizzes. Of the 113 students enrolled in the course, 96.9% (n=107) of students elected to use the week 7 SQ and 92.9% (n=105) of students, used the week 8 SQ, with a 100% completion rate of the quizzes in both weeks. The SQs remained open until the examination period, with students continuing to make use of them leading up to the morning of the examination. In addition, from student logs, it was seen that students made us of the quizzes at all times of the day and night, including the very early hours of the morning.

Of the 62 students who elected to take part in the participant questionnaire, 84% (n=47) of students, agreed or strongly agreed that the quiz had enhanced their knowledge and understanding of the subject matter. This included 78.5% (n=44) of students who agreed or strongly agreed that the quiz had enhanced their understanding of complex formulas required in the subject.

Would students’ perceive the inclusion of instant, adaptive feedback to be beneficial and would they have a preference to the type and structure of the feedback?

In order to assess students’ attitudes to the instant, adaptive feedback they had received in the SQs, students were asked to identify their preferred feedback type. They reported that when an answer was correct, they preferred receiving feedback that included the correct answer as part of the feedback message, with 100% of students finding that extremely helpful or helpful. The try again feedback, without any sort of hint, or guidance was identified by 65% of students as being the least helpful.

Table 1: Students' response to different feedback types

	Extremely Helpful	Helpful	Neither helpful, nor unhelpful	Unhelpful	Very Unhelpful
CORRECT + NO answer	16%	14.5%	17%	37%	16%
CORRECT + answer	56%	44%	0%	0%	0%
Try again + NO hint/guidance	12%	12%	11%	38%	27%
Try again + hint/guidance	61%	37%	0%	0%	2%
Feedback - link to notes	42%	47%	9%	0%	2%

Out of the 62 students who completed the participant questionnaire, 98.4% (n=61) of students reporting having found the feedback clear and easy to follow, with only 1.6% (n=1) unsure. Furthermore, 89.3% (n=50) of students agreed or strongly agreed that the feedback they received had been effective and helpful to their learning. In addition, in the open ended question regarding what students liked most about the SQs, the theme of feedback came up. Below are some of the comments they made:

“I felt encouraged on my way to the right answer instead of stressing over it. That it was clear and simple with answers and hints.”

“Instant Feedback, Multiple attempts and Reasons why an answer is correct or incorrect”

“The instant feedback is actually very handy to have since it can alert you to small details that you might have missed.”

Would educators be able to effectively guide and support students' understanding of complex content from afar?

Data captured in the analytics engine provides educators with insight into students' interaction with the platform. Educators are able to drill down to see how many students are answering a question correctly and whether the feedback being generated is leading to a positive outcome or not. Furthermore, this information provides educators with insight into whether students are possibly experiencing misconceptions, allowing them to adjust their teaching or if necessary the question being asked.

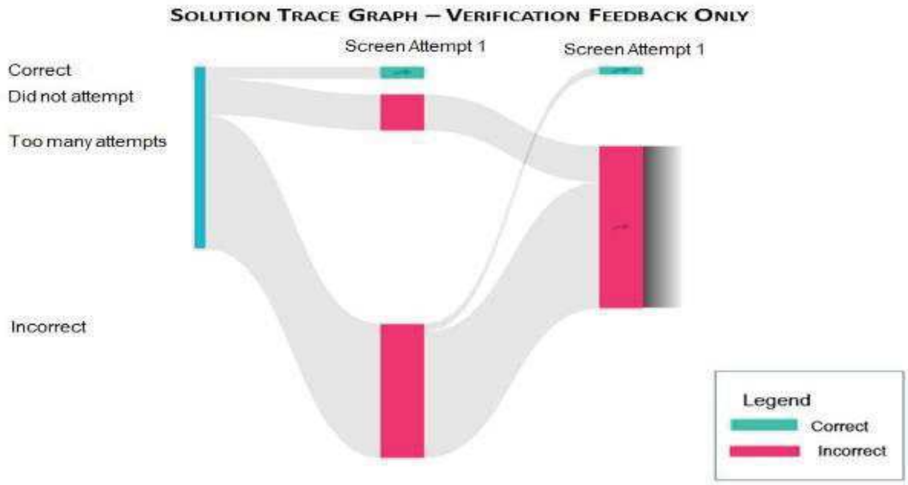

Figure 2: Figure 2: A solution trace graph indicating students' attempts on Question 6

Figure 2, shows a solution trace graph where only verification feedback was generated in a calculation type question that did not include elaborate feedback. The correct verses incorrect response rate on students' second attempt was very low.

In comparison, as seen in Figure 3, in a question that included both verification and elaborate feedback, the feedback provided on the second and third attempts produced 59 correct responses, with only 3 students having to be given the correct answer and explanation before moving on.

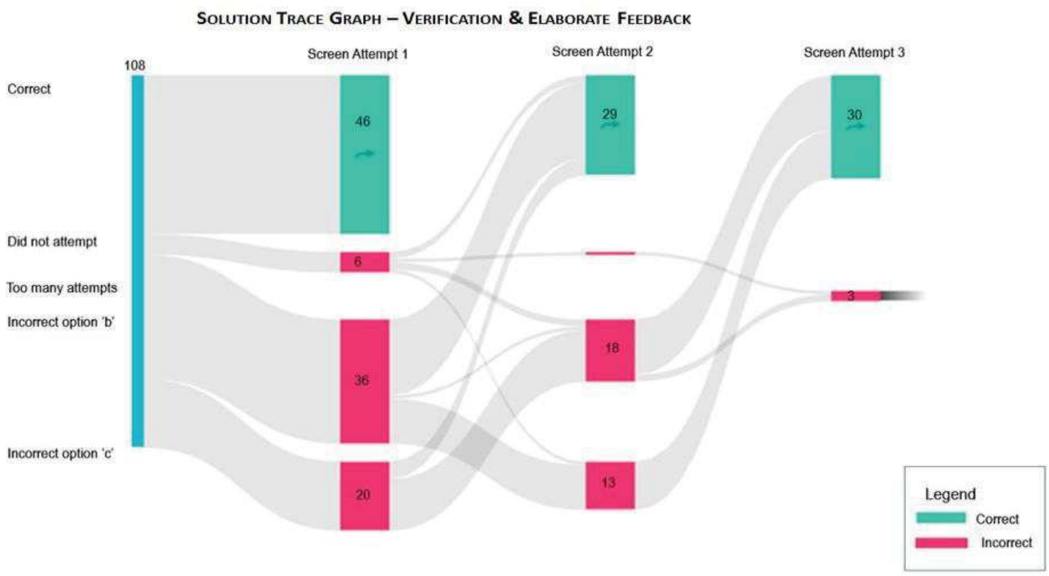

Figure 3: Solution trace graph of students attempts when verification feedback used

In addition, the lecturer noted that the insight students were able to gain from having made use of the SQs, allowed him to set a far more conceptual type of examination question than in previous years where this resource did not exist. Instead of students being asked to simply derive a generic equation, he was able to give them an equation and ask them in-depth questions on their observations and understanding of the situation.

Discussion & Conclusions

Students are unique, with different prior knowledge and individual needs. This diversity is difficult to address in large classes. By integrating technology into face-to-face classes, educators can attempt to tackle some of the issues they face in teaching and learning today.

Our study found that an average of 94.9% of students accessed the Smart Quizzes (SQs). It was evident, that despite the lack of external incentives, students across the academic spectrum elected to utilise the quizzes at all hours of the day and night. It also showed that 98% of students preferred the use of 'knowledge of response' with elaborated feedback when they got a question wrong. Furthermore, evidenced by the 100% completion rate each week, and the overwhelmingly positive comments related to formative feedback, students found the SQs valuable to their learning. As novice learners, learning a complex topic, this resource provided students with support and guidance that enabled them to effectively engage in their learning at a time, place and pace that suited them. In essence, the SQs provided a guided learning context which has been shown by many to support and improve learning outcomes (Kirschner et al., 2006). The SQs did not only provide students with evidence of their knowledge level, but also provided lecturers with insight into the students learning. Input from the lecturer revealed that students appeared to have gained a greater depth in their knowledge compared to students in previous years.

It is noted that future studies could include a comparison of learning outcomes in the form of marks in order to measure learning outcomes.

The Smart Quizzes did not duplicate what was done in class, nor did they attempt to replace the educators, but instead provided students and educators with an effective, complementary learning and teaching opportunity, enabling students to be supported from afar.

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Mixing Teaching Approaches to Maximise Student Learning Experiences

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SESSION: C1: Integration of theory and practice in the learning and teaching process

CONTEXT Postgraduate student education is a highly dynamic environment that experiences significant fluctuations in regard to the make-up of the student cohort and their educational expectations. Like all educators, we seek the best learning and teaching methods to maximise student outcomes. Therefore, the educator must be dynamic and embrace the notion that varying teaching and learning approaches may be necessary – even in the same course/subject.

PURPOSE The aim of this study was to examine how fee-paying coursework postgraduate students perceive different teaching approaches in a traditional-type of course/subject and, therefore, what approaches should be improved/pursued/adopted in the near future.

APPROACH Over a three-year period, a new postgraduate course delivered to cohort of students with diverse educational and cultural backgrounds was examined to see how different teaching approaches were perceived by the students. The course/subject is contained within a traditional chalk-and-talk program taken (mostly) by fee-paying (chiefly overseas) postgraduate students. Two approaches were used sequentially during the delivery of the course - the first was the approach of interactive lectures and supportive tutorials, while the second was based on problem-based learning and with supportive workshops. At the end of the course, formal feedback was obtained from students to see how they perceived the teaching approaches used, and where improvements can be made.

RESULTS Results from the formal student surveys indicated that students appreciated both methods of delivery, with high satisfaction results being achieved for both approaches. The students showed no preference of teaching approach employed, and their performance—as assessed through formal measures (assignments, exams, reporting and presentations)—again showed that both teaching approaches were successful. Informal feedback was also obtained, and it was clear that students felt that the professionalism and availability of the staff were factors that were critical to achieving high student satisfaction outcomes.

CONCLUSIONS It was concluded that the exact method of delivery of the course components did not have a significant impact on the learning perceptions of the students, which was similarly reflected in their assessable items. Both methodologies, and their combined impact, proved highly satisfying to the students. It was apparent that the main factors influencing students were professionalism and accessibility to the staff which, while known, seems to be critical to the postgraduate cohort.

KEYWORDS Postgraduate education, learning styles, flexible delivery

Introduction

With the changing educational environment throughout the world, there are growing demands on educators to be proactive in determining what is the best educational approach to our postgraduate and undergraduate tertiary students. Indeed, this extends to all forms of educational environments, including the TAFE and professional sectors, across all disciplines, with engineering education being just one of them.

Postgraduate student education is a highly dynamic environment that experiences significant fluctuations with regards to the makeup of the student cohort and their educational expectations. This is due in part to the students' varied cultural backgrounds and learning approaches. Like all educators, we seek the best learning and teaching methods to maximise student outcomes (eg Felder et al, 1995 and Mason et al, 2012). Therefore, the modern educator must be dynamic and embrace the notion that varying teaching and learning approaches may be necessary within a degree (or graduate diploma, etc) program, and even in the same subject (which, in some universities, is referred to as a unit and even a course). Interestingly, Prince (2004) found that that "*there is broad but uneven support for the core elements of active, collaborative, cooperative and problem-based learning.*" However, as time progresses the concept of flexible teaching and learning approaches is gaining greater credibility.

It has been known for a while that the so-called traditional chalk-and-talk approach is not an ideal method of education in many contexts. For example, Mills and Treagust (2003) stated that: "*The use of project-based learning as a key component of engineering programs should be promulgated as widely as possible, because it is certainly clear that any improvement to the existing lecture-centric programs that dominate engineering would be welcomed by students, industry and accreditors alike.*" More recently, published work such as Ramsden (2003), Bishop and Verleger (2013), Sano et al (2014) and Borras-Gene et al (2016) reveal that different approaches have different impacts on the engineering student's learning ability. Significantly, the approaches are varied, there is no "one-size-fits-all" approach and they do not all follow the traditional approaches.

Connor et al (2015) pointed out that: "*the only real limitation on cultivating such approaches is the disciplinary egocentrism of traditional engineering educators*". As such, the aim of this study was to examine how fee-paying coursework postgraduate engineering students perceived different teaching approaches in a traditional type of course/subject; and therefore, what approaches should be improved/pursued/adopted in the near future to help enhance the student education experience.

Approach

To look at how students may be impacted through a varied educational approach, this small-scale study was conducted over a three-year period within an initially new postgraduate civil engineering course (in 2015), and delivered to a cohort of students with a diverse educational history (though generally based upon traditional civil engineering training). The students had wide-ranging cultural experiences and, therefore, presented a range of (non-quantified but observed) learning styles and expectations. The course used in this study was entitled "Advanced Water Engineering Practice". It was contained within a traditional chalk-and-talk delivered style masters of engineering program taken mostly by full fee-paying postgraduate students who mostly came from overseas.

The objective of the course was/is: "*Throughout history, human civilization has developed near coastal water bodies. Unfortunately, this essential resource is relatively under threat due to climate variability. Therefore, it is essential that this scarce resource is carefully managed to ensure sustainability of both the natural and built environments. The main* *purpose of this course is to investigate recent developments in the engineering principles and processes that are applied to the design and management of sustainable water engineering related projects. It introduces students to advanced engineering design practice utilising real world design exercises and international design codes. The course delivery mode is a combination of lectures, labs and project based workshops. Professionals from industry may be invited to present case studies on with particular emphasis on Australia.*" This is a rather generic descriptor, with little detail of how the course was to be delivered. To resolve this, students were informed at the beginning of the course that they would experience different teaching approaches throughout, to ensure they would keep an open mind about it. However, they were not made aware beforehand of exactly what the approaches would be.

The course used two sequentially delivered and distinctive learning modules/approaches. The first was the approach of interactive lectures and supportive tutorials, with the tutorials being aimed at working through real engineering problems in a classroom-style setting. This is considered the more normal type of chalk-and-talk approach—albeit that we certainly do not use chalk, and the talking was heavily focussed on students interacting in the lectures and tutorial spaces. It was not a passive delivery approach, but more of an interactive one aimed at enhancing student engagement. These activities were conducted through the first half of the course, with the student's knowledge being assessed through a problem-based assignment and a mid-semester exam.

The second approach used in the course began after the completion of the mid-semester exam. In this part an open-ended problem was set for the students to work through, come up with a solution for, and report on their findings as a team. Rather than lectures, workshops were used, and these were aimed at giving supportive answers to student questions. At the end of this part of the course the students delivered a written report and delivered an oral presentation. The open-ended problem followed on from the initial part of the course and, therefore, they could use the knowledge gained in that section to assist their project formulation and design. For the first two years one academic member delivered the first part, while another delivered the second. In the third year one academic delivered both parts, following the same delivery philosophy.

Formal student feedback was obtained from students at the end of the course to see how they perceived the teaching approaches used, and where they felt improvements could be made. This feedback consisted of both Likert scale data and general comments on the course.

Results and discussion

The results from the formal student surveys used to evaluate the course are presented in Table 1. Students were asked various questions covering their course experience and, for the first two years of delivery, they were also directly asked their thoughts on the two delivery methods.

The results from the surveys, shown in Table 1, clearly indicate students appreciated both methods of delivery, with high satisfaction rates being achieved for both approaches. Indeed, within one standard deviation, there was no statistical difference. This was the case across all questions asked, which covered the assessments, feedback and teaching. The results clearly showed the students had no preference of the teaching approach employed and their performance, as assessed through the formal measures (assignments, exam, reporting and presentations), also showed that the teaching approach used had minimal impact on their performance. That is, the actual teaching method did not influence the overall student performance or how well they perceived their learning experience. This is significant, as there are often calls for educators to move towards non-traditional approaches, but we feel it is usually the quality of the educator that has the greatest impact on student learning and student satisfaction. Hence, one should not always be pushed to use a particular approach, but instead use that which is most engaging to the staff/student education experience.

Table 1: Formal student feedback with regards to various course related questions. The student could respond with a value of 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree)

	2017		2016		2017	
Year of Offer	6/11 Student responses		10/24 Student responses		13/44 Student responses	
Question	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
This course was well-organised	4.7	0.5	4.5	0.5	4.4	0.9
The assessment was clear and fair	4.3	0.5	4.4	0.7	4.2	0.9
I received helpful feedback on my assessment work	4.5	0.8	4.4	0.8	4.5	0.9
This course engaged me in learning	4.7	0.5	4.5	0.5	4.6	0.5
The teaching (lecturers, tutors, online etc) on this course was effective in helping me to learn	4.7	0.5	4.6	0.5	4.7	0.6
Overall, I am satisfied with the quality of this course	4.7	0.5	4.4	0.7	4.5	0.7
The PBL cases were relevant and up-to-date	4.5	0.6	4.1	0.7	---	---
The {theoretical part (first half) used} in this course assisted my learning	4.7	0.5	4.5	0.5	---	---
The {workshop and problem-based learning approach (second half) used} in this course assisted my learning	4.5	0.6	4.2	0.6	---	---

To help explain the numerical score results, examination of the written student feedback (presented in Table 2) clearly showed that these mature students really appreciated both the professional approach taken by the academic staff and the clarity of their required tasks.

Additional feedback was obtained through informal discussions during the teaching periods. One point that became very clear from this was that the students strongly felt that professionalism and availability of the staff were critical factors for achieving high student satisfaction outcomes. That is, students appreciated direct access to knowledgeable and supportive staff (in this case the teaching team, which consisted of two academic staff and no tutors) who deliberately made time for them. In order to manage this in a way that did not encroach too much on staff time, the professional approach to office hours was enforced. The students certainly appreciated this, which is not surprising as we are training professional engineers. This is in keeping with the findings of Uzun and Senturk (2010), who found that a blended group of education approach resulted in students attaining better course achievement.

Table 2: Written feedback from students for a given year

2015
this course have well combination of the traditional learning approach and workshop with waste water treatment plan design. Knowledge about water treatment plant are great and really useful for me. Also the seminar about pond design was great. Theory was very clear the project is good
2016
I found the teacher-student relationship very helpful. Lecturers were very helpful and confident. Topic was very interesting and encouraging. The topic is interesting, and the knowledge will be beneficial. how to analysis and design the some particular structures I able to know information and able to gain some knowledge
2017
I learnt how to apply theories in practical aspect. It gave me the interest to learn further about this subject. This course made more familiar with coastal functions and how to design a coastal structure The way the assignment make you think in practical manner was excellent. The course convenor has a rigorous teaching attitude and a sense of responsibility. Clear method and process to learn The lecturer is patient and helpful. Very well designed. The assessment plan was nicely balanced. Breakup of learning within lectures and tutorials was a good idea to make the course look settle.

In order to investigate the correlation between the SECs and the marks attained, their mean values were compared with those of other courses taken in the same semesters (Tables 3 and 4).

Table 3: Comparison of course marks attained at the end of the semester for this course and the three others held in the same semester (out of 100), 2015-2017

	2015	2016	2017	Mean
This course	64.36	64.96	62.68	64.00
Course 2	72.71	71.33	68.07	70.70
Course 3	72.71	61.89	68.38	67.66
Course 4	65.83	66.46	73.00	68.43
Mean of other courses	70.42	66.56	69.81	68.93

Table 4: Comparison of student responses to the question "Overall, I am satisfied with the quality of this course" for this course and the three others held in the same semester (out of 5), 2015-2017

	2015	2016	2017	Mean
This course	4.70	4.40	4.50	4.53
Course 2	4.50	4.40	4.20	4.37
Course 3	3.80	4.20	4.30	4.10
Course 4	3.50	3.70	3.70	3.63
Mean of other courses	3.93	4.10	4.07	4.03

As shown in Table 3, the average marks attained in this course were always lower than the mean marks of other courses in the last three years (about 5%). By contrast, the SECs of this course were always higher than those of other courses during the same period. Table 3 displays that on average the SEC of this course was about 0.5 (more than 10%) higher. This indicates there is no direct relationship between the marks and SECs of course, and higher SECs are not due to higher marks attained by students.

Conclusions

It was concluded that the exact method of delivery of the course components did not have a significant impact on the learning perceptions of the students, which was similarly reflected in their assessable items. Both methodologies, and their combined impact, proved highly satisfying to the students. It was apparent that the main factors influencing student satisfaction levels were professionalism and accessibility to the staff in a timely and meaningful manner.

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Experiential Learning in Project Management Education

Louis Taborda [a], Li Liu, Lynn Crawford

STRUCTURED ABSTRACT

CONTEXT

Project Management (PM) is a relatively new discipline that has experienced significant growth and acceptance over the last decade. The advance of the PM profession can be related to the continual evolution of the field from its engineering origins into a generally applicable management discipline. The increasing adoption and genericity of PM has seen the Project Management Institute (PMI) predict a significant talent gap with over 15 million new PM roles projected to be added globally by 2020. The growing demand for project managers has given rise to significant changes in PM education and the development of project professionals.

PURPOSE

The research question to be addressed is how the practice-oriented discipline of PM, can utilise experiential learning in Capstone projects to improve the learning outcomes of inexperienced PM students.

APPROACH

The role of Universities in the formal education of PMs has increased in recent times, marking a shift from previously offered technical PM training and professional certification - usually taken as an adjunct to on-the-job training. The need to educate PM concepts and tools to inexperienced students represents new challenges to educators. Capstone projects presents an opportunity to investigate PM students' perception of the value of experiential learning in acquiring practical PM competencies.

The contribution to knowledge this paper makes is to explore effective pedagogies appropriate the education of inexperienced project managers. Mixed methods are applied, including a student survey supplemented by focus groups, to collect the perceptions of the PM students about the learnings from their Capstone unit.

RESULTS

The evolving approach to PM education is discussed with the unique challenges of coordinating a PM Capstone unit that offers an experiential learning opportunity for students. Preliminary findings from a pilot study of PM Capstone students are presented that indicate that while student assessment is a significant concern, they felt it developed their communications and leadership abilities while increasing confidence in their PM capabilities.

CONCLUSIONS

The study indicates the value of PM Capstone units and the key role they can play in the PM curriculum. Resolution of the unique challenges to experiential learning in PM Capstone units needs further research adopt the appropriate pedagogies and assessment methods. This study has wider relevance to the PM profession as it can help set expectations for University PM programs and the job-readiness of future project managers.

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KEYWORDS

Experiential Learning, Project Management Education. Capstone Projects

Introduction

Once upon a time, a project manager could only gain that designation after several years of distinguished experience in their chosen industry. Technical skills like engineering would be rewarded with a promotion to the role of project manager. Only two decades ago, senior managers rated technical competence as the third highest rated characteristic of an effective project manager (Zimmerer & Yasin, 1998). While this appears a high ranking, the authors viewed that as evidence of the waning influence of “technical skills and knowledge of the industry” as a criteria for project manager selection - the other eight out of nine characteristics were managerial in nature. They suggested the results reflected “a basic understanding that effectiveness is directly related to the ability of the project manager to lead and manage more than simply possess exceptional technical skills.”

The role of PM continues to evolve and growing demand (PMI, 2017a) has resulted in new educational pathways for aspiring project managers. The introduction of PM undergraduate degrees, and masters programs for graduates with little or no work experience, is a relatively recent situation that requires more investigation and pedagogical research. While PM courses once trained individuals after several years of work experience in which they had to show proficiency, tertiary education of PMs often reverses that situation.

We now find ourselves in the age of generic PM (Basner, 2008; Crawford & Pollack, 2007) where students can be trained only in PM skills and practices as encapsulated by the PMI’s Project Management Body of Knowledge (PMBOK). This is happening even as PMI’s own Talent Triangle (PMI, 2017b) formally recognises that a Project Management Professional (PMP) requires PM skills in equal measure with leadership and business competencies.

With PMI’s relatively recent establishment of a framework for PM curricula (Kanabar et al., 2014), many Australian universities now offer PM degrees which enrol undergraduate students straight after high school. Students choosing to major in PM may graduate without a deep knowledge of any specific technical or industry domain; effectively making them generic project managers. Similarly, postgraduate programs enrol recent graduates with degrees in other disciplines into PM Graduate Diploma or Masters Programs; their limited work and life experience essentially presenting PM educators with similar challenges as undergraduate students.

While technical proficiency in a domain may now be viewed as less important to being seen as an effective PM, we know little about the pedagogies that are appropriate for these new circumstances. Even where we might understand the competencies required of a successful PM practitioner (Cartwright & Yinger, 2007; Vukomanović, Young, & Huynink, 2016) the educator’s challenge is to help create such an individual. The significant increase in demand for PMs and the resulting interest in the generic discipline as a career choice requires that we adapt our educational approach to the new situation and ensure that educational institutions prepare their PM graduates with the requisite skills and competencies to enter the workplace.

Capstone units have been used by PM educators an integrative course at the conclusion of the PM curriculum for some time (Cesario, 2001). This paper aims to investigate the perceived effectiveness of this project-based, experiential learning approach to better understanding its role in the education of a new generation of PMs. Specifically, we aim to assess the relative value of the experiential learning over traditional lecture-based teaching in the PM curriculum. To achieve this, we describe an evolving methodology and overview preliminary results capturing the challenges faced by educators in the design and delivery of effective capstone units, and the perceptions of PM students undertaking these programs.

Methodology

As a relatively new management discipline taught at tertiary level, educators have studied the application of different approaches to teaching PM knowledge (Shelley, 2015). Our research objective is to improve the learning outcomes for PM students, specifically those taking the project-based Capstone units (Schwering, 2015) which provide an opportunity for experiential learning (Kolb, 1983).

Our research was undertaken in first semester of the 2017 calendar year, with consenting PM Masters students at the University of Sydney. These students were enrolled in the Capstone unit in their final semester of the inexperienced PM Masters Program. The Capstone unit has a duration of 15 weeks inclusive of assessments, and is designed to allow students to work in small groups to undertake a real-world project. The Capstone project provides an opportunity for student to consolidate and apply the PM knowledge acquired in earlier units of study while reflecting on that experience.

Our research design seeks to assess and analyse the student reflections provided as a part of the Capstone unit, supplemented by focus groups designed to inform the research question. Ethical approval for this study was received the Human Research Ethics Committee of the University of Sydney [2017/159] after satisfying concerns about conducting research with students whose work is also subject to assessment. The conditions stipulated by the ethics committee has meant that participation has been limited to those students who provide consent after their student marks have been published and can make themselves available to participate in the research. These constraints have resulted in refinement of our methodology with more structured reflections being required of all Capstone students which serves the dual purpose of better guided student reflections, while collecting their perceptions of the experiential learning offered by their Capstone project. The student reflections represent the data which is to be analysed as a part of the research program; supplemented where possible with focus groups.

This paper describes the first iteration of our research study undertaken at the end of the first semester of 2017 with PM Masters students who completed the Capstone unit. A description of the PM Capstone unit and the challenges provides context for the particular circumstances facing educators. We then present preliminary findings based on qualitative analysis of student reflections and the results of a focus group comprising five students. While a small sample, this does provide a pilot for our research approach with the initial content categorisation offering early insights into the experiences of PM Capstone students. The results also serve to inform and guide our ongoing research into experiential learning, the refinement of PM Capstone units and the wider challenges faced by PM educators.

Capstone Challenges

While PM has a growing set of underlying theoretical constructs that have seen it become a vibrant area of research, it remains a highly practical discipline. Prior to formal degree-level PM courses being introduced in Universities, PM education was provided by technical institutes like the Tertiary and Further Education (TAFE) colleges or professional education bodies.

The PMI has been instrumental in this evolution with the introduction of the PMBOK, and more recently the formation of the Global Accreditation Centre (GAC) responsible for accrediting PM related degree programs in universities. While Capstone projects are a recognised part of the PM curricula (Cesario, 2001; Fan, Thomas, & Anantatmula, 2014), they do present some unique problems for educators.

Teaching PM generically as a management discipline independent of a specific industry domain serves to make coordinating PM Capstone units themselves unique. While this is a consequence of the modern, multi-disciplinary nature of PM, it means that there can be peculiarities in the selection and execution of Capstone projects – which in turn provide PM educators with challenges in assessing the students.

In a PM Capstone, it is the application of PM methods to the project itself that is a key learning outcome; rather than delivery of the desired product that is the project's scope. This has the benefit of giving greater choice to PM students, allowing them to select projects from any area, on a range of topics – because the topic itself is a secondary objective to the application of PM principles to the exercise. One consequence of this is that the tension between the need to produce plans and status reports for the initiative which can result in the teams neglecting to provide the promised benefits to project sponsors. While this tension between planning and doing may also be found in PM professionals, educators must be on guard that assessment methods do not have the unintended result of making students focus on the creation of PM artefacts at the expense of delivering on the project scope and goals.

Perhaps one of the biggest challenges faced in the Capstone unit is finding suitable real-world projects for the students to undertake. While many institutions put the onus on students to bring their own topics for their Capstone projects, this is not realistic for inexperienced students who do not have an employer's workplace from which to source projects. As a result, some institutions distribute the problem of finding suitable candidate Capstone projects across the resident academics, with mixed success. From experience, these projects can be limiting, offering students' highly specialised topics that advance the research interests of the sponsors with limited opportunities to apply and exercise the students' PM competencies. Given the nature of a PM Capstone project can be about anything (so long as there is an opportunity for students to plan and execute the scope within the course's timeframe) we have looked to source real-world projects from local, not-for-profit (NFP) organisations including local PM industry bodies, that has the benefit of providing students the experience of working with external sponsors who expect an outcome from the project.

The fact that a Capstone project's learning outcomes and assessments are necessarily biased (60:40 in our units) towards the creation of PM artifacts rather than delivering the sponsor's required scope, meant that students acknowledged they looked to select simpler projects at the start of the Capstone course. Assessing the value the student teams provided their sponsors is a difficulty faced by markers due to the variability between the projects. This is compounded by the fact that the sponsor's feedback can be unreliable and overly generous as they do not want to negatively affect the students' marks.

The execution of the Capstone project by a team, or groups of students represents another contentious and challenging aspect of a Capstone unit. Our PM Capstone program requires projects to be conducted in groups of 4-6 students who must together work to deliver the sponsor's requirements. Special consideration may be given in exceptional situations, but by default, all PM Capstone projects are conducted in groups. We are aware that not all PM Programs insist on Capstone projects working in teams and some Universities have policies on individual assessment that discourage group work due to the difficulty of gauging an individual student's contribution. Yet, most projects in the real-world are undertaken by teams which surely encounter similar difficulties in rating the contribution of individuals to a team's overall performance.

If teamwork is challenging to assess, the team formation process also presents a dilemma. Many units of studies allow the students to form their own teams, where they work with their friends or develop collegial relationships, and as a result, students prefer to work with these colleagues for their PM Capstone projects. While allowing students to self-organise and select their own teams is clearly the path of least resistance for a Capstone coordinator, this is not generally an option in industry where teams are more likely formed based upon the availability of resources. As a result, our Capstone program has chosen to form teams based on a matching algorithm that can assign teams based on selected individual characteristics so these teams are balanced in some capabilities (e.g. English language skills) yet share other characteristics in common (e.g. prior grades or degree of commitment).

We currently utilise the CATME team formation and peer-evaluation software (Ohland et al., 2012) in our Capstone units, which provides a means of creating compatible groups and moderating group assessments based on the teams assessment of each member's contribution.

Student Perception of Capstone Projects

Initial content analysis of the Capstone students' reflective diaries and the one focus group conducted indicate that the students have some strong views on their Capstone project experience. The following lists the preliminary findings which indicate the themes that the authors hope to explore further as more student data is collected:

- Challenges of teamwork in Capstones

  By far the most frequently raised concern of the students was the formation and performance of Capstone teams. Complaints of team members not doing their share, not being capable or simply wanting to do the bare minimum were common. Even as peer-assessments were used to mitigate the problem of unequal contribution by students (Rainford, 2014) the students feared that their results were negatively impacted by poorly performing team members and so the quasi-random team formation method described above was challenged on several occasions.

- Development of communications and soft-skills

  Even as students reported frustration working with their team members and sometimes difficult sponsors, they often concluded that the experience provided them valuable learnings. While they lamented issues they faced with team members, like similar project-based learning studies (Jollands, Jolly, & Molyneaux, 2012), the students felt this challenged them to be better communicators and find ways to motivate and lead their team. Some other examples of learnings included the routine acts of writing emails to sponsors and preparing for or recording meeting minutes.

- Value of Capstone units relative to other PM units

  When asked specifically about the value their felt their experiential Capstone offered over the other traditionally thought PM units, the common answer was that it provided the opportunity to practice or acquire new soft-skills. This was balanced by the opportunity afforded to plan and execute a small-scale project end to end but the value was moderated by the nature of the specific project the students worked on.

- Range of Capstone project candidates

  Students felt that there was variability in the Capstone projects that the different teams worked on and some were too simple or uninteresting. When probed "simple projects" appeared to be projects that related to organising events or undertaking marketing activities for PMI or NFP sponsors. They reported that the PM methods "overloaded" these smaller projects that did not appear to need the full range of PM deliverables that their assessments required. There was also a dependency on the project sponsor with students reporting that there was "not a sense of urgency" about some projects. The suggestion was made that projects from different industries should be offered for those who wanted to exercise their skills in specific domains.

- Job readiness

  Without significant work experience of their own, the students found their Capstone project provided them with evidence of an actual project of undertook that they could discuss in job interviews. Even as there is debate about the role of universities in making its students work-ready (Moore & Morton, 2017) this view supports earlier finding that project-based learning experiences are important for developing communication skills (Jollands et al., 2012) and the Capstone unit can help students gain practical experience to meet expectations (Hussain & Mohamad, 2015). Students presenting their Capstone posters to industry professionals at PMI Chapter events found the opportunity to exercise their communication skills invaluable, pointing to future collaboration opportunities for educators to work more closely with industry bodies.

- Results of undertaking Capstone unit

  Asked how the Capstone project changed their perception of their own capabilities, the focus group participants broadly felt that it improved their personal confidence. What they had learned in traditionally taught units seemed theoretical with the Capstone providing them opportunity to apply their PM knowledge and use it to achieve an outcome. Even as they acknowledged that the one-semester project was only modest in scale, it went through all the project phases from initiation to delivery. This offered students the opportunity to practice what they had learned and therefore gain a better understanding and appreciation of the PM role.

Conclusions and Limitations

The preliminary results reported in this paper indicate that PM students undertaking the one-semester Master Capstone unit had concerns relating to teamwork and assessments, but overall found value in the experience which gave them the opportunity to apply and consolidate their learnings from the more traditionally taught PM units. In addition, students reported that their Capstone project provided real scenarios and learning that they could use in job interviews to demonstrate their PM knowledge.

Our research results have the limitation of a small sample size that potentially suffered from selection bias as participation was voluntary and only the more dedicated and engaged students attended the focus group. However, our research is ongoing and the richness of the student feedback provides confidence that the methodology is sound. Even with limited data principally from a single cohort of Masters students, we believe our findings offer important pointers to the value of incorporating greater experiential learning opportunities for inexperienced PM students – potentially beyond just the Capstone units this research was focused upon.

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Professors' Discourses on Why Underrepresentation Matters

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CONTEXT

While much scholarship has explored the causes of women's underrepresentation in engineering, very little has explored why certain groups of stakeholders care about underrepresentation in the first place. Arguments for increasing the numbers of women in science and engineering tend to fall into several clearly identifiable and recurring discourses, including equity or social justice, workforce concerns, legal concerns, "access and legitimacy" concerns, and economic competitiveness concerns. However, nearly all prior research on this topic has been based on written documents. In that sense, sources are 'closed' to further inquiry about authors' thoughts or motivations. What happens, then, when such questions are posed in interviews in which participants are asked to explain or justify the discourses they engage about why underrepresentation matters?

PURPOSE

The research question addressed in this paper is: Do engineering professors believe that women's underrepresentation in engineering is a problem that needs to be fixed, and, if so, why does it matter?

APPROACH

In-depth interviews were conducted with 39 engineering professors at three different institutions in the United States. Among other questions, participants were asked if they thought underrepresentation was a problem, and is so, why. Responses to that question underwent open, and then axial, coding, resulting in three categories of discourses.

RESULTS

By far the most common discourse, with 35 participants mobilising some version of it, was the idea that increasing the numbers of women in engineering would lead to 'better engineering' in some way. However, follow up questions revealed that this discourse is in need of further interrogation. The other two discourses engaged were a social justice discourse, and that underrepresentation actually is not a problem that needs to be fixed.

CONCLUSIONS

The discourse of 'better engineering' warrants further critical reflection. The finding that some participants do not understand why underrepresentation matters can provide insight to those working on change efforts by highlighting issues that they should address in their work.

KEYWORDS

Staff, Professors, Underrepresentation, Discourse

Professors’ Discourses on Why Underrepresentation Matters

Introduction

Rationales for increasing the numbers of women in science and engineering tend to fall into several clearly identifiable and recurring discourses, including equity or social justice, workforce concerns, legal concerns, “access and legitimacy” concerns, and economic competitiveness concerns (Beddoes, 2011; Lucena, 2005; Pfatteicher & Tongue, 2002; Slaton, 2010; Thomas & Ely, 1996). At various times, legal, economic, and social justice discourses have each been engaged, with economic competitiveness ones being more common than social justice ones. The various discourses mobilised led to different outcomes and had different levels of “success,” indicating that the way in which underrepresentation is problematized shapes the solutions enacted and what they accomplish (Slaton, 2010).

The body of scholarship summarised above is based on written documents. In that sense, the sources are “closed” to further inquiry about authors’ thoughts or motivations. What happens, then, when engineers are asked about these issues in person? To answer that question, engineering professors were asked if they thought women’s underrepresentation in engineering was problem, and if so, why. This paper presents findings from those interviews.

Methods

Semi-structured interviews were conducted with 39 engineering professors at three different public institutions in different parts of the United States (18 women and 21 men) in 2014 and 2015. The interviews averaged 60 minutes in length and were audio-recorded and transcribed. They were conducted in-person, except for two that were conducted via Skype. Interviewees were a mix of Assistant, Associate, and Full professors and from all major engineering disciplines. Several interviewees also held administrative positions. Seven identified as Asian or Asian/white, two identified as Black, two identified as Indian, and the remaining twenty-eight as White. Ten different nationalities were represented. Recruitment was done through a combination of maximum variation sampling and purposeful random sampling (Patton, 1990), and recruitment efforts for this project have been discussed in detail elsewhere (Beddoes, 2015).

The interview protocol was designed to cover a wide range of topics that have been identified in prior literature as contributing to the gendering of engineering and/or women’s underrepresentation in engineering. The overarching aim of the interviews was to better understand what and how engineering professors think about gender in engineering, women’s underrepresentation in engineering, and how they make decisions around gender in their teaching. This paper presents findings from one question posed at the beginning of the interviews. Participants were asked if they believed underrepresentation was a problem, and if so, for whom it was a problem, or in other words, *Why does it matter that women are underrepresented in engineering?* All responses to that question were analysed with an open coding approach (Charmaz, 2006) through which the three primary themes identified in this paper emerged. Many participants mobilised more than one discourse, which is reflected in the numbers given at the beginning of each subsection below. In recognition of the diversity of participants, they are identified with numbers in this paper, so as to avoid any implication of cultural or national origins that pseudonyms can imply. Quotations were edited to remove false starts, stammers, and “crutches of speech,” such as “like” and “um.” Words in square brackets were added for clarity.

Findings

Better Engineering

The most common discourse, with 35 participants mobilising some version of it, was the idea that increasing the numbers of women in engineering would lead to better engineering in some way. For the purposes of this paper, five versions of this idea were subsumed within the "better engineering" category:

1) engineers should be representative of the people they serve;
2) diversity brings more creative and innovative design ideas;
3) we want the best brains working on engineering problems;
4) having more women on teams leads to better environments or team dynamics, and
5) economic competitiveness.

These ideas are similar to what has been called elsewhere "access and legitimacy" (Thomas & Ely, 1996), "economic competitiveness," "professional service and representativeness," and "women's attributes" (Beddoes, 2011). Each of these is a somewhat different perspective warranting its own analysis in future work, but, given space allotted, they are categorised as "better engineering" herein. The following response from P5 is representative of many answers in this category:

> *Fifty percent of the population that we design, build, and maintain things for are women, but 80 percent of the engineering, well actually more than that in many cases, are men designing things the way that they perceive them. That's going to be a natural bias towards designing things more male-oriented than for the population as a whole.*

What is most interesting about the "better engineering" discourses however, and what has not been revealed in prior research based on document analysis, is what happened when participants were asked follow-up questions. The first follow-up question was if they could give me examples of how women in engineering have or would lead to better engineering. For various reasons and given the nature of semi-structured interviews, not every participant was asked these follow-ups. But of those who were, not one participant could provide an example. When asked this question, one of three things would happen: 1) They would say they had no examples; 2) they would give a response that did not actually provide an example of what they had just said; or 3) they would "backpedal" and start talking about something else entirely. Providing a sense of these responses is difficult here given space constraints, but the following exchange with P33 is one example. She does not provide examples of women in engineering but instead shifts to discussing interdisciplinarity:

> *Interviewer: Could you talk a little bit more about examples you've seen of how diversity breeds creativity or innovation?*
>
> *Interviewee: I'll give you examples of things to think about in the lab. My students, we spend upwards of five years working together on a project. Right about the third year, we're all thinking the same because they're all thinking like me because I'm training them, and that becomes difficult for us to see solutions to problems that we run into in the lab. We think everything is perfectly fine until we go to a conference or we talk to another colleague, who is completely outside our realm, who goes, "But why that?" So, that's an easy example of how you see diversity of thought bringing creative solutions to a problem. Things that we couldn't think about based on our expertise, somebody just outside of our field can look at it and say, "Well, this sounds like this." And we go, "Oh, my God. You're right." So, that's an example that you see in scientific research.*

In a similar way, P21 shifted her discussion to examples from finance rather than engineering:

> *I can't think of a specific example. I've never worked outside academia. I've always been in science, science and engineering, like academic. I think the example from the financial sector that I just mentioned, that's one where diversity works. I have heard from rehab design teams, when you're trying to design a technology that you should be a little diverse, but I don't have any specific examples.*

The other follow-up issue I attempted to get participants to talk about was if they thought "diversity" was able to be expressed or manifest in current engineering cultures or classrooms. Prior literature suggests that it often will not be. While a couple of participants said "No," most participants to whom this was asked did not understand the question.

Social Justice or Equity

The second most common discourse, with 15 participants mobilising it, was essentially a "social justice" or equity discourse. Only one participant actually used the term "social justice" when answering this question, but several types of responses conveyed ideas that can most succinctly be categorised as social justice arguments. Within this category of social justice, there were two distinct lines of reasoning. The first was essentially that everyone should be free to choose the best career for him or herself without being influenced by gender stereotypes or biases. As P1 explained:

> *I think it matters in a sense that it's important to live in a world where people feel like they can pursue whatever career path makes sense to them. And so if there are barriers that are preventing women from entering engineering based on the culture that makes them feel unwelcome or other issues like that, that's a big deal.*

P11 expressed the same idea, saying:

> *I don't think all women have to be engineers, but I think they have to have been given the chance to decide for themselves and not to be turned away from it due to things like, "Oh, I don't want to be viewed in a certain way," or that they had bad experiences from a math teacher or from certain interactions.*

The second line of social justice reasoning was that engineering is a highly paid profession and excluding women from highly paid occupations is unjust. For example, P17 said:

> *I think that women need access to choices and professions where you can make a solid living for their own independence and their own choices in life. I think that engineering, for whatever reason, pays very well and has some career satisfaction in it for people if it fits them.*

While she did not think it was the most important reason, part of P18's response was that "engineering is fun and creative but also very financially rewarding as well, and if we're excluding large swaths of a population, fifty percent, from these activities, then it has certain ramifications. The financial ones are pretty clear." The one participant who used the term "social justice", P24, said:

> *There's sort of a…for want of a better phrase, I guess I'll say a kind of moral or social justice kind of issue…It's a, relatively speaking, lucrative profession – there are some that are more lucrative – but everybody should have a shot at it, so there's all of those aspects.*

However, P24 then went on to say that she thinks economic competitiveness arguments are more compelling to engineers than social justice arguments are:

> *In some sense, the same thing from a different perspective is if I want to do the best job of providing a skilled workforce for the United States, I don't want to say, "Okay, I'm going to exclude 50 percent or 70 percent of my talent pool from the group I'm trying to train." That just doesn't make any sense…And okay, well, if you're not adequately and effectively educating*

your entire population, you're going to suffer economically. I like those arguments, because it separates out any kind of amorphous social justice kind of arguments. It's just business, you know? If you're not really utilising your talent pool, somebody else is going to beat you…If I'm arguing an issue like that, I find the quantitative arguments are better at defeating perspectives on what's morally correct.

Whether or not quantitative, "business" arguments are in fact more compelling is a question that warrants further research.

Underrepresentation Is Not a Problem that Needs to be Fixed

After social justice, the third most common response was that it actually does not matter that women are underrepresented in engineering, or that participants were not sure if or why it matters. Fourteen participants expressed some version of this idea. More specifically, the versions of this idea were:

1) If choices are made on a level playing field, then underrepresentation is not a problem;
2) Diversity of thought matters but that is not related to underrepresentation of women;
3) I am not sure that it does matter; and
4) The world does not need more women doing what engineers do.

Four was a unique perspective expressed by only one participant.

Some participants said that underrepresentation is only a problem if choices are not made on a level playing field. For instance, P6 and P13 related their responses back to the social justice discourse, explaining that once people are free to make choices within an equal playing field, then it actually does not matter if far fewer women than men choose engineering:

P6: If it matters, I think it matters for my daughter, for example, not to say that "No, I can't do it [engineering] because there isn't one [a female engineer] or because women don't do that [engineering]. So I think from that side it does matter. I think after we're old enough and we're all here, I don't think it really does [matter].

P13: I actually often have that question as well. Why are we so concerned? We need everybody in society to take on different roles, and if some women want to do engineering, let them do engineering, but a majority don't. So what? They're going to do other wonderful things. So I often wonder why we push this, and I think for me I just want to make that opportunity available for women, not to say you have to be an engineer, but to make it an option.

Other participants said that diversity of thought is important for engineering, but that diversity does not necessarily come from bringing more women into engineering. As P34 put it, "I think gender is a poor proxy for diversity of thought." These explanations were similar to the "better engineering" discourse then, except the difference was that these participants did not think better engineering would necessarily come from women.

P23's response reveals how some participants struggled to answer the question, interspersing some reasons while simultaneously questioning whether or not underrepresentation does in fact matter:

These are good questions, because as you say in your consent form, it helps me to think about what my actual position is. As I say, I haven't really thought about things so much. So is it [underrepresentation] a problem? I'm hesitant to just say "Yes" outright…I don't know the answer is necessarily "Yes." I mean, it's certainly good to have a diversity of opinion. And it's always good for women to know that they have that opportunity. But if, for example, it was suggested that women chose not to pursue this in general, if once all the other factors were taken out there was still some bias, would that necessarily be negative for engineering, the *actual engineering itself? I don't know. The engineering culture probably would be beneficial to have women in. But in terms of actually getting things done, it wouldn't necessarily, in principle be. I don't know. That's a difficult question to answer.*

P35 was more certain that it does not matter:

I don't necessarily think it's a problem. I'm trying to search for why it would be a problem. I can't see why it would be a problem necessarily. Maybe – I have all these caveats – maybe that's the man thinking or something. I don't know. But I just don't see it as a problem and I do believe individuals should do what they feel like is going to be fulfilling to them.

While not espousing this idea themselves, two participants mentioned that they often hear colleagues saying underrepresentation does not matter.

P10 was an outlier who was critical of engineering and its role in the world, specifically its ties to the military-industrial complex. He said that we probably do not want more women (or people in general) participating in that system:

I actually have some questions about why would you want to change it [underrepresentation]. So is that something that's valuable to the female students that'll go off and do it, is that a good thing to direct their lives towards participating in that system? Or is it maybe better to have them for themselves go off and do something different than solve problems using science and technology, which is how I define engineering. So I'm not sure if it [increasing the numbers of women in engineering] is what needs to be done or what anybody wants to be done. I'm not sure.

This participant was the only one who expressed such fundamentally critical views about engineering. Before moving on, it may be worth remembering here that these are the people who cared enough to take the time out of their schedules to participate in an interview about gender, so the fact that so many within the sample population did not necessarily think underrepresentation was a problem was surprising.

Discussion and Conclusion

The first finding to note was that the discourse most often mobilised – better engineering – was done so without there being evidence or examples to support it, and without recognition of the ways in which minority voices are often not heard in engineering. We can call the idea that simply adding women, or other minorities, to engineering somehow changes engineering the "myth of bodily diversity." As one of my participants put it, "gender is a poor proxy for diversity of thought." A facile belief in bodily diversity necessarily leading to "better" engineering is a problem because those who study engineering cultures, both in education and practice settings, continually find engineering to be dominated by masculine cultures in numerous ways (Faulkner, 2009; Mills, Ayre, & Gill, 2010; Mills, Franzway, Gill, & Sharp, 2014; Riley, 2008; Tonso, 2007), and we know from teams research that women's voices and ideas are often ignored, or not "heard" (Beddoes & Panther, 2017, In Press; Meadows et al., 2015). Such realities are obscured in the "better engineering" discourse when it does not account for cultures and practices in male-dominated environments.

A second finding of note was the prevalence of social justice discourses. Other researchers have observed a decrease in the use of social justice arguments since the 1980s (Etzkowitz, Fuchs, Gupta, Kemelgor, & Ranga, 2008; Lucena, 2005; Roberts & Ayre, 2002; Slaton, 2010). Their prevalence in this study is noteworthy then in contrast to engineering education publications, where social justice arguments are scarce (Beddoes, 2011). The findings also suggest that social justice arguments may be more compelling to at least some engineers than is often assumed, despite the fact that they have lost ground in favour of economic competitiveness arguments. As noted, however, one participant did believe that social justice arguments are not compelling to the engineering community and that she strategically chooses not to use them for that reason.

A third finding of note was that almost the same number of participants who engaged a social justice discourse said that the lack of women in engineering was not a problem in need of correction. Given that this was a population who chose to take time out of their schedules to participate in an interview about gender and engineering, it is reasonable to assume that the percentage of those who do not think underrepresentation is a problem is much higher among the entire population of engineering professors. Before changes to make engineering education more inclusive gain widespread support, it would seem that much work first needs to be done to convince more professors that underrepresentation is a problem.

Asking engineers if and why they think underrepresentation is a problem allowed deeper insight than has been gleaned from document analysis alone. It revealed that although variants of the "better engineering" discourse were readily mobilised, follow-up questions were met with an inability to provide examples or evidence for that discourse. Furthermore, it seems scant attention is given to thinking critically about the ways engineering cultures may inhibit diversity. On the other hand, social justice discourses emerged as more prevalent than may have been expected based on prior document analyses. Many participants were also willing to say that they do not understand why anyone should care about underrepresentation, or, more strongly, that they actually do not think it is a problem. Further research into how engineers think about women and gender in engineering may present one important way forward for those who do wish to increase women's representation in engineering. Deeper understandings of the relationships between framings of a problem and interventions designed to address it can shed light on these trends.

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Making a difference: creating opportunities for undergraduate students to contribute to humanitarian engineering projects

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Context

Within the student body of engineering undergraduates there are a number of students with passion and enthusiasm for becoming involved with Humanitarian Engineering (HE). However there are generally limited opportunities for them to contribute in practical ways to HE projects locally or overseas. Organisations such as Engineers without Borders and other Non-Government Organisations working in HE generally recognise the limited resources of overseas or local partner organisations to support volunteers. How can the energy and enthusiasm of students be engaged in an effective way to make a difference to HE projects?

Purpose

The purpose of this study was to investigate the most effective mechanisms for providing opportunities for students to contribute to actual humanitarian projects.

Approach

Four case studies are presented here to compare and contrast the success of student teams contributing towards solving a number of different engineering challenges. The nature of the projects varied from literature reviews to design and analysis of projects. Students have participated through extra-curricular activities and honours thesis projects. The experiences of these students have led to the development of new HE courses at UNSW Sydney to provide opportunities for students to gain course credit for their endeavours.

Results

The case studies have had varying levels of success in achieving the aims of engaging students in HE projects and contributing to tangible outcomes. It is anticipated that the results will show that success depends on a well-defined scope, mentorship, drive of students, buy-in and/or need of the project partner and an established partnership where cross-cultural exchange is supported.

Conclusions

Providing opportunities for students to contribute to areas that they are passionate about enables them to become more engaged with their engineering degree and develop different skills further than they would in a traditional engineering program. Significant time commitments are required from students and academics and project partners are required to make these projects succeed. Mechanisms to enable students to count these endeavours for course credit are likely to enable students to prioritise these time commitments.

Keywords

Humanitarian Engineering, student led experiences

Introduction

Interest in Humanitarian Engineering (HE) in Australia has been steadily increasing over the last decade. At the University of New South Wales (UNSW Sydney) this interest has until recently been implemented through student involvement with Engineers without Borders student chapter and similar student clubs and service organisations. Many of the activities that the students get involved with have focused on high school outreach or inter-university competitions and collaborations. Many students would like to further increase their involvement in design and research for HE projects. However due to the students' limited technical skills the opportunities for them to contribute in practical ways to HE projects locally or overseas can be limited. In general meaningful volunteer opportunities require extended placements to build relationships and fully understand the wider community, technical and cultural context for project tasks. Organisations such as Engineers without Borders and other Non-Government Organisations working in HE generally recognise the limited resources of overseas or local partner organisations to support unskilled volunteers.

How do we best then harness the enthusiasm and energy of undergraduate students and provide opportunities to contribute to HE projects? A number of different options have been trialled at UNSW Sydney and this paper reviews the outcomes and lessons learned from each of these approaches. The first and second case studies review two projects where students carried out extended literature reviews and project synthesis for Australian engineers working overseas on HE projects. These projects could be considered as examples of service learning which has been shown to "extend students' learning in ways that cannot be accomplished in the class room" (Bettencourt, 2015). Two teams of students were formed in the second half of 2014 and in 2015 and this paper discusses these projects as case studies in building student skills and interest in HE. The third case study reviews the involvement of students in HE research through enrolment in an honours research thesis course. Finally the development of two final-year student project courses at UNSW Sydney is discussed as a flexible mechanism for recognising student effort with course credit. The paper is structured to present the details, successes and failures from each of the case studies, concluding with a final synthesis and recommendation section.

Case studies

Case Study 1: extra-curricular student research project 1

This project was developed to work with a UNSW Sydney alumni who was undertaking a volunteer placement in a South Asian country. The volunteer placement was 12 months and the volunteer's job was to assist the local small team in developing systems to assess and protect the water catchments of the country. The context to the project is that the country had low levels of development to date. The major demand for water from many catchments is for hydroelectricity schemes, which have a number of requirements in terms of the quality of the water. The impacts on the catchment from these hydroelectricity schemes include increased discharge velocities as well as the higher temperature of the released water. Increasing urbanisation of the capital also creates pressures on the nearby catchments. Small scale agriculture also creates pressure on catchment health with unrestricted access of livestock to watercourses causing some erosion problems. Compared to many parts of the world, the catchments are in relatively good condition.

Due to limited resources, detailed catchment management plans can only be developed for the most at-risk catchments. Therefore a multi-criteria ranking approach was required to ensure that the different competing pressures and attributes of different catchments can be sensibly compared. The UNSW Sydney student team was tasked by the volunteer to research and compare existing approaches for ranking catchments and to make suggestions as to the best system that would take into account the unique pressures on and characteristics of the specific catchments of interest.

A team of 8 students was selected from members of the EWB student chapter by calling for expressions of interest in this project and the second project described below as Case Study 2. Students ranging from first year to fourth year were selected. The student team split into two sub groups based on the task with one group researching other examples of catchment classification methods and the second group considering multi-criteria approaches for ranking. This group was also responsible for researching the context of the country of interest and its catchments and using this information to guide the thinking of both groups in terms of ensuring that solutions were appropriate.

The work by the students on the project was mainly carried out over a 4 month period. An additional three months was required at the start of the project to formulate the idea and define the scope. Student involvement and enthusiasm was strongly affected by the timing of the project with respect to the academic year. In the middle and end of semester students had less time available for extra-curricular activities due to assessment tasks and exams. Initially it was thought that one advantage of having a team of students at varying stages of their degrees was that not every student would have the same assessment schedule and they therefore could work continuously on the project. In reality the work was driven by a few individuals so the progress was not as smooth as expected and students found it challenging to work in a group of otherwise unconnected people with different aims and desired outcomes (Downey et al., 2006).

Student meetings with an academic mentor were arranged once every few weeks to provide some accountability throughout the project and to workshop issues and problems. The academic mentor provided the communication link between the volunteer and the students. Once a draft report was prepared, then a skype meeting was arranged between the volunteer, academic mentor and three of the students for them to present their findings and rationale. This meeting proved to be really useful for the students in comprehending the context of the work in a developing country and the constraints on resources both in terms of financial and human resources. Although this had previously been explained in emails and group meetings, the contrast between what the students found to be world best practice and the realities of working in a developing country was very stark. In some ways it may have been better to organise this skype meeting earlier in the project although until the students were immersed in the materials, earlier meetings may not have been as productive. Students also identified that an initial briefing working in low-resource and low-capacity environments would have been useful to better prepare them.

The final report was prepared in just enough time for the volunteer to incorporate in his reporting and presentation to the government department. Students found that working on the project was helpful for understanding what a professional role in HE involves rather than an idealist view of this field of work that may be formed from professional seminars. For all the students this was the first time that they had the opportunity to work on a project where the motivation was not good marks but by making sure that they did a good professional job as well as the benefit of knowing that they have contributed (Litchfield & Javernick-Will, 2015).

Case Study 2: extra-curricular student research project 2

Project 2 was set up with similar aims to project 1, working with a UNSW Sydney alumni based at a research institute in East Africa. The alumni also had an adjunct position at the UNSW Sydney so this project also aimed to strengthen links between the two organisations. As part of a funded grant, the researcher had opportunities for three small projects featuring targeted literature searches and design tasks that students at the UNSW Sydney could contribute to.

It was identified by the researcher that this collaboration was a good opportunity for both learning and contribution from the students from UNSW Sydney and for the East African Water, Sanitation and Hygiene projects to receive some extra scientific input. However, early on in the project initiation it was emphasised that the risks for the researcher was that the time taken to communicate with the students to answer questions and give guidance outweighs the research/design output gained. This highlights the important balance that is required in providing students with meaningful and useful experiences in HE whilst not creating a burden on overseas organisations.

Due to the researcher's other supervision experience and research commitments, her expectations for the nature of the collaboration with the UNSW Sydney students were much clearer and formally arranged compared to Case Study 1. It was suggested by the researcher that three teams of 2-3 committed people each would be ideal, and that it was necessary to be selective about to who was to participate in this opportunity. As such, a formal student selection process was implemented with students required to provide their existing skills, time availability and nominating their preference out of the three projects on offer.

This process of selecting students and providing descriptions for the scope of the projects and more detailed work briefs took longer than expected due to workloads and barriers to communication such as email misunderstandings and frequent power and internet network cuts in the East African country. For this project, a student led the communication and liaison with the overseas researcher. This was primarily because the academic mentor who initiated the project was not able to devote sufficient time to working with the students during its setup and implementation. The difference in positions and project experience (researcher vs student) and also the lack of long term personal connections contributed to the extended time period being required to set up the project, which was in the order of 6 months. The importance of building networks and communication channels over time is clearly highlighted by this experience.

A Terms of Collaboration document was signed by all selected participants, and further details about each project was provided to each team. The three project teams initially had a face to face meeting with the researcher when she was visiting the UNSW Sydney. The research staff from the Eastern African institute who would be the point of contact for each of the three projects joined this meeting via skype. The skype session was a good experience for the students to learn first-hand what the projects were about, and provided an opportunity for cross-cultural exchanges between the students and researchers. From this meeting, it was expected that each team would liaise with their designated project leader from the East African research institute.

This process did not run as effectively as intended. This was due to decreased motivation from students due to exam period and other university commitments. Additionally, the projects did not progress due to various constraints faced by the researchers in the East African institute (staff on maternity leave, overseas travel, delays in contracts leading to reduced staff numbers) which resulted in no resources being available to follow up links to the student projects at UNSW Sydney. Additionally, the East African project officers were hesitant to reply directly to UNSW Sydney students, without consulting the project leader. The main reasons that they were not confident in replying directly was due to being judged for their English and also were not always sure of what the students were asking for. The development of an informal connection between the two groups before the project outcomes would have overcome this barrier.

This experience highlights the difficulties faced when trying to establish a project with researchers working in an institute that has many priorities and limited resources. As the research to be undertaken by the students at UNSW Sydney was not deemed a core priority, the limited resources of the organisation were allocated to other functions.

A key lesson learnt from this experience is that the logistics of the collaboration need to be arranged prior to the start of a university semester, as to provide maximum time for students to engage in the actual research assignments. These logistics include: required time commitments from students, skills matrix of interested students, general project scope, training in cross-cultural communication, background information on the partner research organisation and nature of the collaboration (i.e. the Terms of Collaboration Document).

Case Study 3: Honours research

Honours research projects are an important component of engineering degrees providing students with the opportunity to experience a research project as well as working one-on-one with an academic or research only staff. For students with an interest in HE the opportunity to undertake a research topic in an aligned area has in the past relied on either the student having a clear research question or finding an academic with current HE research projects. Through the UNSW Sydney partnership with Engineers without Borders, the opportunities for students to undertake an honours research project on a HE topic has substantially expanded. Over the last two years as academics and students have become more aware of opportunities, the number of students undertaking such research has increased (Table 1).

Table 1: Number of students undertaking EWB Honours Research at UNSW Sydney

Year	Number
2012	2
2013	0
2014	0
2015	0
2016	8
2017	7

Historically in the School of Civil and Environmental Engineering at UNSW Sydney, honours research in HE is the first opportunity that many students have to integrate HE into their program. This means that students need significant support to develop both their research skills, in common with all students undertaking honours research, as well as their ability to understand the context and challenges of research affecting developing and/or remote communities.

Honours research requires students to develop their understanding of how research is undertaken which for many students can take the first few months of their honours project (Linn, Palmer, Baranger, Gerard, & Stone, 2015). One of the challenges for students undertaking a HE topic is that they also need to define the scope of a project in a context that they are not familiar with. Frequently, students are in direct contact with partners from developing countries in order to share data or find out additional information. To facilitate this type of communication students need awareness training in common cross-cultural communication strategies when working with partners with lower capacity, such as poor command of English and limited access to internet. It is important to note that this is likely to include more than developing what is commonly referred to as ‘global compentence’ (Hunter, White, & Godbey, 2006) because the constraints of low capacity organisations and countries require more than just empathy, current event knowledge and positive attitudes (Hunter et al., 2006). Support for both students and supervisors in these early few months of honours research is vital to build research momentum and to ensure that the literature review process allows the student to effectively define the research problem statement. Another specific challenges faced by students include preparing the documentation for ethics approvals for research which is relatively uncommon in many traditional engineering research projects.

With plans to introduce new HE courses in coming years, it is expected that students undertaking honours research in HE will have a stronger background on appropriate frameworks for analysing the context and constraints in these problems which will enable them to more quickly determine the research problem scope and project requirements.

One of the benefits of doing an EWB honours research project is that the EWB partners have identified the research project need, which is satisfying to students knowing that their research outcomes will have an impact. Dean and Van Bossuyt (2014) note that the traditional semester model of such projects can lead to some difficulties in achieving these impacts for honours students and can lead to less optimal project designs. Depending on the research topic, connections from these projects allow students to build their industry and research section connections which are useful for students who want to pursue international development sector careers. As per the extra-curricular case studies, research in HE allows students to further explore the realities, pressures and constraints that are an important part of international development. Ensuring that projects are people-centric rather than design-centric is a useful parallel that should be emphasised with these projects as with larger HE projects (Dean & Van Bossuyt, 2014).

Case Study 4: Student-initiated project and Humanitarian Engineering courses

To address some of the weaknesses addressed above at UNSW Sydney in terms of involving students in HE, a number of courses have been developed over the last 2 years. The first is of these is a student-initiated project course which allows for cross-disciplinary engagement of high achieving student teams to develop, manage, solve and report on a project, or solve a significant problem that they have identified or developed with support from an academic mentor. Although not designed for HE specifically, projects like those in Case Study 2 could lead to students pitching ideas for this course. This course was approved in 2016 but has yet to have any projects proceed. Future research will evaluate the learning outcomes from the course.

In addition to the broad student initiated course, a new course on Fundamentals of HE has been approved to commence in Semester 2, 2018 at UNSW Sydney. This course will enable engineers to analyse and design infrastructure and appropriate technology to support the well-being and welfare of individuals and communities in disadvantaged circumstances. This includes developing countries as well as marginalised or remote communities in Australia. The course will provide students with frameworks to analyse and respond to complex multi-disciplinary engineering problems. The usefulness of case studies for HE has been demonstrated by Perez-Foguet, Oliete-Josa, and Saz-Carranza (2005).

A second course, HE Project will allow students to further develop their skills and learning around international development by providing students the opportunity to undertake a design project related to HE. This may include a field work component if appropriate which would provide students with further context and skills in HE. The course will be problem based, with context aligned with clearly identified needs for a marginalised community, either locally or internationally.

These courses have been designed to address a number of points that the earlier three case studies have raised, namely 1. that students are underprepared for the context of HE work when undertaking an honours research project in this area, 2. to ground students' expectations of the nature of international development and HE in the reality of field work in resource constrained contexts, and 3. to provide extrinsic motivation for students to learn through structured assessments. Finally as noted by Swan, Paterson, and Bielefeldt (2009), although involvement in project based and service based learning is beneficial for students, academics find that involvement in these projects not rewarding in terms of promotion. By providing formal courses for credit in this area, the contribution of academic staff in mentoring students on projects can be recognised through academic workload models.

Fieldwork provides engineering students with very valuable learning outcomes. To deliver quality teaching and reduce risk academics are required to supervise fieldwork, especially where subject credit is awarded. The time commitment for academics are presently not well acknowledged or compensated for at most universities. The time to recruit and prepare students frequently occurs outside of the teaching period. For example, fieldwork usually occurs in summer and winter breaks but recruitment activities happen during semester which takes time away from normal teaching and research commitments. In order to continue offering valuable fieldwork opportunities, universities need to address these special travel and time requirements for academic staff involved in fieldwork teaching.

Conclusions and recommendations

In this paper, four case studies of students contributing to HE projects have been described. The main recommendations that will be useful for other universities and organisations aiming to implement similar programs for student engagement are summarised below.

Student groups working on short term HE projects require a dedicated academic mentor. Experience suggests that fortnightly meetings are required to ensure progress and accountability of the student teams to a client. Although in theory these meetings could be with the external research partner, UNSW Sydney experience shows that international volunteers and NGOs are already under substantial resource and time pressures so an internal mentor/client at the University can ensure progress and provide students with a first level of support to address concerns and problems. When there is a conflict, it is our opinion that the benefit needs to be provided to the NGO rather than the students at UNSW Sydney. This tension between the benefits to students compared to the benefits to the community where the project is based has been explored by VanderSteen, Baillie, and Hall (2009) and these issues are vital for universities working in this space to explore. Other possible problems of such service based learning projects from universities have previously been identified by Riley (2008) and Schneider, Leydens, and Lucena (2008). Our experience shows that without a substantial commitment of time and enthusiasm from the academic mentor these projects have not achieved the desired aims. Mechanisms for recognising mentors for their contribution still need to be developed.

There is a clear need for focused support for academics supervising HE research projects early in the first semester through a workshop or similar to help train academics in assisting students in HE research including requirements and processes for ethics approvals, how to define a suitable scope of possibly large ‘wicked’ research problems as well as clear expectations of support provided by Engineers without Borders or similar research partners.

In all these case studies, skype or face to face meeting with the NGO or researchers is also vital to allow students the opportunity to get direct feedback and information on the specific challenges of working in developing community contexts. These structures also help to train students in professional skills by the academic mentor modelling to students’ professional communication styles, project management skills and reporting methods.

New courses to provide students with course credit for participating in HE research are a promising way of providing further extrinsic motivation for students to complete the research projects. This will benefit both the students and the academics involved with the programs through formal recognition of their contribution in workload models. Further work is required to capture the actual work load involved with field work courses.

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STEM for Women and Ethnic Communities in Aotearoa (New Zealand)

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SESSION

C4: The role and impact of engineers and the engineering profession in the wider community.

CONTEXT

In order to raise awareness of science, technology, engineering and mathematics (STEM) focused jobs in the future, educational providers need to expand their delivery methods to reach a wider audience. The women and ethnic communities have been rapidly increasing in recent years, hence an opportunity has arisen to cater to their need for STEM information and aim to increase the understanding of STEM and to build awareness of career paths in STEM areas among refugee and migrant communities in Aotearoa. There are different educational programs based on specific disciplines and they all share a single goal of using innovative methods of teaching STEM subjects to minority and under-served communities.

PURPOSE

The aim of this research is, to understand the perceived challenges ethnic and refugee groups face in adopting STEM and propose a holistic approach along with the existing community partnership in New Zealand.

APPROACH

The framework used for this paper is conceptual analysis and interview method. This paper critically examines delivery methods of STEM programs across Aotearoa. Interview with ethnic communities and their reflection is also used in presenting a holistic approach.

RESULTS

We aim is to propose a holistic approach along with community partners to encourage STEM subjects in women and ethnic communities. Recommendations are offered for ways in which mainstream educational institutes can assist in building the capacities of women from ethnic communities in partnership with community partners.

CONCLUSIONS

The future of the scientific workforce and the advancements of science are dependent on the supply of talented people in STEM disciplines.

Many students that are interested in a STEM career during secondary education ultimately do not graduate in a STEM discipline.

In particular female and minority students are even less likely to enter tertiary education intending to major in a STEM subject, but if they do so they are more likely to switch away from that STEM major before completion of studies.

Clearly this is a waste of possible STEM talent and this research makes recommendations in order to improve opportunities to develop this talent.

KEYWORDS

Outreach Programmes, Ethnic Communities, STEM Education

Introduction

The acronym STEM is fairly specific and refers to science, technology, engineering and maths. There is, however, no standard definition of what constitutes a STEM job. A recent report on New Zealand STEM issues identifies possible occupations or professions that can benefit from a strong STEM educational background. STEM jobs could be considered to include natural and physical sciences (including mathematics), engineering, information technology, health (including veterinary sciences), architecture, and agricultural and environmental. (Buntting, Jones, McKinley, & Gan, 2013).

Almost every aspect of our modern-day living is impacted by maths and science. The greatest advancements in our society from medicine to mechanics have come from the minds of those interested in or studied in the areas of STEM. Although still relatively small in number, the STEM workforce has a huge impact on a nation's economic growth, and overall standard of living. STEM jobs are the jobs of the future.

Many students enter tertiary education intending to study a particular major, but change before completion of their chosen course. This is particularly true for students commencing STEM subject courses. Women and minorities are even less likely to persist in a STEM courses than are male and non-minority students. The percentage of women and minorities employed in STEM disciplines has been increasing over recent years but there are still significant gaps remaining (Huang, Taddese, & Walter, 2000). There are possibly two reasons for this. Both groups are less likely to select a STEM study in the first place and if they do they are unlikely to remain in that subject (X. Chen, 2009).

It is clear that the importance of high level STEM subjects is seen as crucial worldwide for countries to meet their economic objectives in an extremely competitive global commercial market.

In New Zealand the last few years have seen increasing government acknowledgment of the importance of science and innovation to New Zealand's economic and social future. One result of this has been the establishment, in 2011, of a Ministry of Science and Innovation, later incorporated into the new Ministry of Business, Innovation and Employment.

Another was the 2009 appointment of Sir Peter Gluckman as the inaugural Prime Minister's Chief Science Advisor. Science education was to be a key focus of this role, and in 2011 Professor Gluckman, (Gluckman, 2011) in a paper entitled Looking Ahead: Science Education in the 21st Century, set out his view that:

"A forward-looking science education system is fundamental to our future success in an

increasingly knowledge-based world".

He goes on to explore how New Zealand's science education system could be strengthened to contribute to our development as a "smart", innovative, knowledge-oriented country, capable of addressing the serious questions we will face in the future, and how we can "engage and enthuse" younger New Zealanders in science. He makes the case for the importance maths and science and that "science literacy" should be a key focus of science education.

"New Zealand must embrace science and technology and innovative thinking as a core strategy for its way ahead. There is no doubt in my mind that a population better educated in science, whether or not they will actually use science in their career, is essential." (Gluckman, 2011)

Given these views how can we continue to waste the potential of ethnic woman to New Zealand and the contribution that they could be making to the future New Zealand Economy?

Encouraging greater female and minority participation in STEM careers provides a clear route to raising participation numbers while bringing on board an under- represented talent pool. The challenge here is not new, there have been campaigns and initiatives in this area and the female and minority groups and participation rates have barely altered. Anything that can be done would benefit STEM professions greatly.

New Zealand's population is super diverse, reflecting the waves of different settlers from many decades. Groups of migrants have included Polynesian settlers, Europeans such as the British and the Dutch, and people from the Pacific, East Asia and South Asia Ongoing migrations up to the present time mean that New Zealand has populations of people born overseas who have migrated here, as well as diverse well-established communities who identify themselves as New Zealanders (Ministry of Social Development, 2008).

Diversity of New Zealand has rapidly increased in the last ten years with 34 percent of the current population being Maori, Asian and Pacific community. People who were born overseas form an increasing proportion of New Zealand's population. Pacific and Asian migrants' entry into New Zealand are set to rise in projections made up to 2038 (Statistics New Zealand, 2016). This has positive impacts such as filling gaps in the labour market and enriching connections, but there are also potential challenges to social cohesion that can arise through increased diversity. There are number of factors influence migrants and refugee settlement in a country (Ministry of Social Development, 2008). Recent migrants may spend more time finding a job and a place to live, learning a new language and upskilling themselves according to the employment market. These communities need support in a new environment in terms of what educational and career opportunities exist and how to go about accessing them.

There is a digital divide among refugee ethnic groups and it is based on inequalities in physical access to and use of digital technology, the skills necessary to use the different technologies effectively and the ability to pay for the services (Alam & Imran, 2015). Providing suitable opportunities, information and skills development can support refugee migrant groups and provide social inclusion in New Zealand community. The diversity is also reflected in the gender gap. The science, technology, engineering and mathematics (STEM) industries offer many job opportunities, but in New Zealand only 28 percent of these roles are held by women. While women make up 64 percent of people studying for a Bachelor of Science, the majority of those are in health subjects, with less than a quarter studying engineering and just over a third working towards a qualification in information and communications technology (ICT) (Brown, 2016).

This paper makes an attempt to understand the existing landscape of New Zealand diverse population especially women. Paper also highlights some outreach initiatives by central government and corporates, challenges and proposes a holistic approach by building partnership with the local communities of New Zealand. The framework used for this paper is conceptual analysis and interview method. This paper critically examines delivery methods of STEM programs across Aotearoa. Interview with ethnic communities and their reflection is also used in presenting a holistic approach.

Literature Review

Diverse Landscape of Aotearoa

The ethnic and cultural diversity in New Zealand has been referred as the changing mosaic. Ethnic diversity of New Zealand has rapidly increased in the last ten years. The population group of New includes Pakeha/Western European New Zealander, Maori/indigenous people, Pacific Island communities, and what is considered 'other' ethnic groups (comprising people from Asia, Latin America, Africa, Central and Eastern Europe, and the Middle East) (Ministry of Ethnic Affairs, 2013). New Zealand is the fifth most ethnically diverse country in the OECD. One in every four residents in New Zealand was born overseas, and New Zealand has one of the highest immigration rates in the world (Ministry of Ethnic Affairs, 2013) New Zealand began to experience super diversity in the mid-1990s, as the sources of immigration expanded from Pacific Islanders to include a significant proportion of immigrants from Asia (M. Chen, 2015). New Zealand also has a long history of accepting refugees, and currently has a quota to accept 750 refugees each year. The top four countries of origin are Iraq, Somalia, Syria, Sudan, Vietnam and Ethiopia. In terms of gender, there were slightly more male (56 percent) than female (44 percent) refugees. Poor experience or outcome of refugee and ethnic affects the social and economic outcomes for New Zealand.

Super diversity means that there is no “business as usual” for any organisation or country (M. Chen, 2015). Diversity of New Zealand is not a new phenomenon, but the level of immigration occurred in the last ten years mean that those not born in New Zealand has passed the critical mass. Diversity of New Zealand has rapidly increased in the last ten years with 34 percent of the current population being Maori, Asian and Pacific community (Karmokar, 2016). Super diverse groups display strong ethnic and national identities, strong ethnic peer contacts and good English language proficiency (M. Chen, 2015). This group has endorsed integration in the society through the process of adopting the cultural and social values of New Zealand along with their values of their host country.

In New Zealand, Auckland is one of the world’s most multi-cultural cities; according the 2013 Census (Statistics New Zealand, 2015), almost 40% of the city’s population on were not born in New Zealand. New Zealand has become one of a small number of culturally and linguistically super diverse countries. Auckland is rich in culture and diversity, with a youthful population on, this project addresses the ques on: how can the new genera on engage in science and technology. The talent pool to diverse community is varied. Few have higher qualifications with rich experience from their home country but few haven’t got an opportunity to be exposed to the education and explore their strengths and interest area. Yet, they have got strong passion and eagerness to learn and do something in a new country.

STEM: Women and Ethnic Community

It goes without saying that females are underrepresented in the STEM subjects. Women are always being in minority when it comes to STEM professions. The technology and roles in STEM are rapidly growing all over the world. New Zealand being a small country, we cannot meet the demand of the economy unless we increase the supply by preparing women to take up these roles.

Engineering is typically viewed as masculine, competitive and impersonal. These are qualities that are not aligned with our images of what women are. The more masculine the branch of engineering (e.g. mechanical) then the less likely it is that women will be attracted to it or excel with it (Stonyer, 2002). Instead women are more likely to be attracted to careers with a more social context.

The foundation of a STEM career is laid early in life with school, parental and society perceptions shaping career decisions. The transition between high school and University being a critical moment when many young women turn away from a STEM career path. A recent survey by Unesco reports that “for the cohort of graduates in education, humanities and arts, social sciences, business and law, and health and welfare, where nine out of ten countries women outnumber men” (Morley & Lugg, 2009).

Work by Aronson et al highlights that psychology in young women in their development at high school and reports that,

“Girls do every bit as well in their graded work as boys do but girls lose their confidence as they advance through the grades and will do more poorly than boys in timed tests, despite getting good grades. One reason for this loss of confidence is the stereotyping that kids are exposed to –in school and in the media and even in the home- that portrays boys as more innately gifted in maths. Without denying the fact that boys may have some biological advantage, I think that psychology plays a big part here,” (Aronson, Fried, & Good, 2002)

Over the last two decades’ women in New Zealand has been underrepresented in STEM fields (Thomas & Drake, 2016). It has been argued that most of the women’s qualification in New Zealand have been around arts, social science and education. The women participation and employment at the senior roles in schools and various tertiary institutes is not very encouraging. IT has been found that there are very few females who are Heads of Departments (HODs) in science faculties in New Zealand universities. Universities namely, AUT, Massey and Lincoln universities has no female staff at Head Of Department level in Science (Women, 2014). The number of women participants in these prestigious awards such as Marsden Fun and the Royal New Zealand Research Fund is very less. In 2010, out of 371 successful applicants only 33 were women (Women, 2015). Within this group of women, it is not known how many were from ethnic background.

There are initiatives aimed at encouraging women and diverse groups, such as the Maori, Pacifica Island communities to enrol in STEM subjects. On the contrary, very little is known about the initiatives targeting a group in ethnic communities, consisting of Middle Eastern, Latin American and African (MELAA) and South East Asian people to participate in STEM subjects. There are well established researches around disparity, gender gap and women in STEM but not many research and statistics that addresses women in STEM from ethnic communities. There are researches and articles on gender disparity but did not put issues of colour in the context (Thomas & Drake, 2016).

Table 1: Participation in STEM Careers (Thomas & Drake, 2016)

	European		**Maori**		**Pacific**		**Asian**		**MELAA**	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**	**Male**	**Females**
Civil Engineers	92.1	7.9	93.8	6.3	88.5	11.5	83	17	93.8	6.3
Quality Surveyors	86.7	11.7	86.4	13.6	81.8	18.2	73.4	26.6	71.4	28.6
Industrial Engineers	92.3	6.7	88.2	11.8	100.0	0.0	76.7	23.3	57.1	42.9
Mechanical Engineers	98.3	1.7	98.6	1.4	94.3	5.7	93.7	6.3	92.9	7.1
Software Engineers	90.4	8.7	87.6	12.4	87.9	12.1	87.5	12.5	90.6	9.4
Computer Engineers	94.8	4.9	93.8	6.3	87.5	12.5	91.6	8.4	100.0	0.0
Architectural, building and survey technicians	90.9	8.3	100.0	0.0	100.0	0.0	81.8	18.2	0.0	100.0
Electrical Engineers	97.5	2.4	94.4	5.6	93.3	6.7	95.2	4.8	100.0	0.0
Fitters	97.6	2.3	90.5	9.4	86.2	13.8	89.3	10.7	100.0	0.0

Table 1, shows the representation of women in STEM area from all communities such as European, Maori, Pacific Islands, Asian and MELAA. Compared to male, the representation of women is very poor. European women have still some participation in STEM careers when compared to zero representation from Maori, MELAA and Pacific people.

However, a complete specific data on the ethnic minority women is limited by the lack of consistent follow up on these groups by various government and other responsible community organisations. The lack of data among ethnic women group has been found to be an issue in other countries as well and not limited to New Zealand. Reacher's and scholars have contributed towards discussion of women in stem but lacks statistics on women of colour.

It is evident that the general population of women are underrepresented in the STEM subjects, the ethnic community will be doubly disadvantaged in the STEM professions and employment area. Technology and entrepreneurial activities are very common interests identified in the diverse population. They have different cultural and language skill sets, social background, perspectives and ideas that can contribute to the New Zealand economy, but lack information on how to go about it and what sort of industries to be aware of and apply to. By providing guidance and networking opportunities, we can help build their confidence and STEM contacts in a new environment.

Challenges in Bringing Stem to Women and Ethnic Communities in Aotearoa

Ethnic communities experience unique challenges due to their backgrounds and have higher levels of disadvantage than the population in general. Getting employment is still the main area of challenge and, along with English language for older people and women, remains the main challenge going forward. Upskilling to the current requirements of the employment especially in the rapid changing IT environment is one of the major challenge. In addition, they may resent the public cost associated with support programmes for ethnic communities (Ministry of Social Development, 2008). It is also suggested that sometimes they are reluctant to seek help from mainstream as they perceive that these services would be unable to meet their cultural and religious needs. Nevertheless, refugees can face complex information and communication challenges that may lead to social and economic problems (Leung, 2010).

New Zealand has many ethnic communities and it is one of the complex scenario to understand the disadvantages of ethnic communities. Indigenous people, Maori's are disadvantaged in the sense of suffering past colonial injustices. Most of the Pacifica people are from Pacific Island nation who are disadvantaged by socio-economic and health outcomes. Pacific peoples have worse economic circumstances than the overall population, with the majority of Pacific peoples living in areas with the fewest economic resources (Ministry of Ethnic Affairs, 2010). Asian people are better off when compared to other ethnic communities as their number of tertiary graduates are higher than other ethnic communities. MELAA is one of the largest ethnic community that represent vulnerable refuges and migrant population. The ethnic MELAA communities arrive in New Zealand through skilled migration, family reunions and refugee status. Refugees in the MELAA group are mostly from Iran, Iraq, Afghanistan, Palestine, Syria, and Kuwait in the Middle-East (Statistics New Zealand, 2013).

However, refugees and migrants have a strong desire to seek meaningful employment and contribute to life in New Zealand (MBIE). Providing informal network and community based services are important for enduring the older and especially the younger people into the mainstream economy. In order to understand STEM practices among refugee migrants and to accommodate their needs requires a holistic approach towards educating, re-training, adopting and confidence building. Research specifically associated with migrants and refugee migrant groups implies that while digital technology is considered to be helpful for them, it can also be a barrier if it is expensive and difficult to access (Migliorino, 2010). There are many factors such as culture, language, education level, socio economic conditions and communication preference, influencing the adoption and upskilling to the STEM areas among refugee and migrants (Helsper, 2008; Mara, Babacan, & Borland, 2010). Women from these communities are discouraged from pursuing science and technology roles. This leads to a very less number of females pursuing science, maths and technology courses at tertiary levels. Things needs to be done in the MELAA and other communities to promote females to take up STEM related careers in order to promote gender equality in the workforce. There also exist stereotype mindset and workplace culture in New Zealand, particularly the long hours, lack of visible role models and transparency in pay (News, 2014).

Outreach Initiatives

New Zealand governments are putting STEM top of their agendas. In NZ Minister Joyce has recently allocated extra funding for engineering degree courses, stating a NZ need for an extra 500 engineers a year (Cumming, 2014). He is also making money available to encourage teachers to teach STEM subjects in pre-tertiary education. (Although there has been little actual activity in the latter)

In recent interview with the New Zealand Herald (Cumming, 2014) Former Minister Joyce was quoted as saying,

"Science and Mathematics will provide jobs for our children, Science and Mathematics is and will continue to be responsible for our high standard of living. Science and Mathematics will ensure that New Zealand increases its economic standing internationally."

The New Zealand Government have recognised STEM education as a vehicle for economic advancement and preparing the future generation for the rapidly changing workforce. There are efforts by the Government to promote entrepreneurship and small business development in New Zealand and within this there are also efforts to support science and technology skills among minority ethnic communities. Thus, the link between universities with the industry is encouraged in tertiary education. This is seen as a catalyst in achieving economy goals of New Zealand (Thomas & Drake, 2016).

The pursuit of STEM to drive economic growth has seen a shift in the alignment of Government agencies from single, small policy agencies such as the Ministry of Research, Science and Technology, to the creation of the Ministry of Business, Innovation and Employment, which brings together science and innovation, economic development, immigration, consumer affairs, building and housing. There are many initiatives such as Girl Boss(https://www.girlboss.nz/),ShadowTechDay(http://www.voxy.co.nz/technology/5/253192) ,Unlocking Curious Minds (http://www.curiousminds.nz/actions/community/women-and-girls/) and Maker a hood (https://socialinnovation.aut.ac.nz/reinventing-south-auckland-as-a-maker-city/).

Discussion and Recommendations

By now there is a convincing body of work to demonstrate the gender gap and the low participation of ethnic minority women in STEM field. There are plenty of research efforts and initiatives undertaken by government and private organisation to encourage participation. In spite of that such efforts the results are not promising. The challenges discussed in the above sections have highlighted few issues such as lack of inclusion policies targeting ethnic minority women, different in the traditional values of a diverse women, social views and traditions about gender stereotypes, work life balance and education institutional framework. Based on the ethnic landscape of Aotearoa, we propose recommendations as a way forward to encourage participation of women and ethnic minority in STEM field.

- ***Providing resources at the right level.*** Most of the resources are directed towards tertiary institutions and universities to encourage students. The real need for the resources is in the schools and colleges. Providing some pathways for teachers to upskill in the subjects and address diversity. One such approaches could be to run on-campus education for teachers to equip themselves with the current knowledge.
- ***Changing STEM pedagogy in Tertiary Education***. Traditional theoretical science pedagogy doesn't always connect with such individuals who may learn better through doing hands-on activities. One of the strategies that support educational engagement is through hands-on workshops and getting inspired by seeing what can be achieved. These comments are not confined to any particular gender. As Richard Miller of Olin College, USA reports many modern students are highly motivated to tackle the Grand Challenges (Vest, 2008) of our age but do not see the narrow study of physics and mathematics to be the key to tackling these problems. They are often seeking to make a positive difference in the world and the lives of people. They

also do not see the study of engineering science and mathematics as being directly related to the problems that they see or care about (Miller, 2010). Miller argues that engineering curricula need rebalancing and requires students to be more involved in "maker" projects less time spent in lectures that involve learning just in case knowledge about topics that are never actually needed.

- ***Reimaging of STEM education and careers***. Little has changed in the way STEM education and careers are viewed by society. They are often perceived to be a male domain and dirty. A recent Australian report notes that students have observed that engineering and physical sciences curricula tend to be crafted with over use of masculine stereotypes and examples such as automobiles, rockets and weapons. (King, 1993). Another report from the US similarly observes that the typical engineering curriculum and culture is "at odds with the value systems of most young women and minorities and probably at odds with many talented students of any race and gender" (Blue et al., 2005). The skills required in STEM careers are many and varied and require much broader so called soft skills not just narrow technical skills. Many Universities are now moving to a far more inclusive curriculum that take into account the backgrounds, interests and views of all members of a diverse society.
- ***Encouraging women participation and employment*** in school and tertiary education in senior roles, school head, and heads of department or deans.
- ***Providing teachers and mentors that relate to diverse community.*** The values of countries of origin will have an influence on their beliefs about STEM subjects. One of the issue of gender imbalance lies with attitudes, values and beliefs in different countries. For instance, the belief in few ethnic countries that men are physically superior to women.
- ***Provide opportunities to connect STEM educators*** and their students with the broader STEM community and workforce especially from their own cultural background.
- ***The initiative for the STEM projects*** *should not only be initiated by the government but by other diverse community groups as well.*

Conclusions

The very low female representation in STEM fields is clearly not due to women lacking the necessary abilities to succeed, but relates to a range of reasons such as the lack of women studying the required subjects at school to gain entry to technical degree subjects. There is currently a requirement for strong Mathematics and Physics qualifications that deter many from embarking on a technical career. Whilst these subjects are beneficial it would be more important to create an enthusiasm and passion for STEM during school years rather than concentrating on mathematics and physics. Greater emphasis should be placed on recruitment and training of STEM qualified school teachers that could create this change of emphasis.

In addition to this STEM subjects in general, and especially engineering need to be recognised as professional worthwhile career choices by society and in particular by teachers and career advisors. If more young women were made aware of careers that can be challenging, satisfying and possibly a good fit with their value systems then an increase in the percentage of females involved in STEM could increase. Year on year this would create a multiplier effect, that as more and more women followed STEM career paths the gender balance would become more equal and a third reason deterring women following STEM careers that of careers dominated by males, would become less significant.

The second area covered in this paper relating to the difficulties that ethnic community to New Zealand have in following STEM careers in New Zealand.

Many of the recent ethnic migrants do already have technical qualifications obtained in their country of origin but not recognised in New Zealand. They are therefore not able to follow their career path here and often are forced into unskilled occupations. This seems to make no sense when there are many technical areas that are experiencing shortage of skilled people. Mathematics and Science teachers, medical doctors and dentists for example. If their existing qualifications are lacking in some areas it would be hugely beneficial for the government to fund conversion courses to allow this sector to be able to practice in New Zealand. This could be funded by way of grants that were conditional on the migrant student completing the course and practising their career for a period of time.

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Towards an informed course design

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CONTEXT
This research was motivated by a desire to identify barriers to academic success in a first year (concept rich) electrical engineering course. Misconceptions of key concepts of electrical circuit theory are known to be carried from high school into first year university classes. If such misconceptions are not identified and overcome, students will likely lack confidence in this discipline, struggle academically in first year electrical courses and be unlikely to continue with further study in this area. Central to our research methodology has been the desire to properly separate “know that” knowledge from the “know how” knowledge usually tracked in programme and course design via institutional and professional graduate attributes. Thus a question central to our investigation has been how course design and pedagogy can be improved to simultaneously ensure both appropriate conceptual progression and the development of the required “know-how” knowledge.

PURPOSE
The initial questions that motivated this research were to identify whether there were specific barriers to success in a particular course and, if so, to determine the key features that should be considered in making consequent changes to the curriculum design. Early results of our research pointed toward fragmentary learning and haphazard development of conceptual understanding. These early findings encouraged us to focus our investigation on whether there was a better way of systematically approaching the unfolding of key concepts in a course so that student understanding and their ability to generalise (i.e. the so-called far-transfer problem), and then apply that generalised understanding, could be improved.

APPROACH
On-line tutorials were developed to support and further develop conceptual understanding rather than merely giving practice in the development of procedural knowledge. Students were incentivised to complete these tutorials and to complete questionnaires which examined their learning styles and motivation. The quantitative analysis and interpretation of student performance in these tutorials and their responses to the questionnaires was enriched by interviews conducted with students, teaching assistants and lecturers. Student performance in the coursework and the exam was analysed in relation to their survey responses and performance in on-line tutorials.

RESULTS
The principal factors to emerge are that misconceptions and a poor ability to generalise and engage in far-transfer seem to be the consequence of learning circuit understandings as isolated fragments. Such behaviour is exacerbated by an over-reliance on summative assessment practices bound to assessable fragments of understanding and curricular design which permits too much teacher (and student) choice of which topics to cover, thereby fracturing the epistemic foundation leading to a procedural approach which limits students’ ability to generalise to unfamiliar settings.

CONCLUSIONS
This project has identified several of the key barriers to be considered in the development of an engineering course which seeks to embed learning in connections between propositional and procedural knowledge and assist educators in maximising their efforts in creating student learning opportunities.

KEYWORDS
Engineering course design, Conceptual understanding, Epistemic Ascent

Background

This research was motivated by a desire to identify barriers to academic success in a first year electrical engineering course covering circuit theory, instrumentation and electromagnetics. Misconceptions of key concepts of electrical circuit theory are known to be carried from high school into first year university classes (Parker & McGill, 2016; Smaill, Rowe, Godfrey, & Paton, 2012) . If such misconceptions are not identified and overcome, students will likely lack confidence in this discipline, struggle academically in first year electrical courses and be unlikely to continue with further study in this area.

A novel feature of this research is the collaboration that took place between engineering academics and postgraduate (engineering) researchers and colleagues from the Faculty of Education. This served to bring a different lens to bear on this issue, thereby better integrating educational theory and class-room practice for engineering course design and delivery. This cooperation brought into sharp focus a little recognised misinterpretation of Vygotsky (Vygotsky, 1962) that some would argue has bedevilled current education systems – namely the idea that meaning is created in what students do. Central to our research methodology has been the desire to theoretically separate "know that" knowledge from the "know how" knowledge usually tracked in programme and course design via institutional and professional graduate attributes (Winch, 2014). The realist approach we use locates *meaning* in the concept itself and *understanding* of the meaning in the student's ability to apply the concept (after Vygotsky). By distinguishing between 'knowledge-that' (conceptual knowledge) and 'knowledge-how' (procedural and practice knowledge) in this way, we want to know how students acquire both conceptual understanding, and in particular how they connect the two forms of knowing which leads to subject mastery.

The initial questions that motivated this research were to identify whether there were specific barriers to success in a particular course and, if so, to determine the key features that should be considered in making consequent changes to the curriculum design for this course. The collaboration with colleagues from another disciplinary area brought a different gaze resulting in a broadened focus on the wider question of how best to integrate course design to simultaneously meet the requirements of the three key elements of curriculum, pedagogy and the development of a disciplinary identity.

Methodology

Evidence was collected about:
(i) how the course design of a Year 1 generic engineering course accommodates the needs of students transitioning from secondary school to 1st year studies,
(ii) how the Year 1 course design prepares students to move to their 2nd year studies,
(iii) lecturer and student teaching and learning experiences,
(iv) expert lecturer views on the selection and teaching of Engineering concepts.

The data collection involved quantitative and qualitative methods:
(a) A pre-entry Year 1 Questionnaire (the 'Ready for First-Year Quiz' - RFFY),
(b) A questionnaire to Year 2 Electrical Engineering students about their Year 1 experience in Engineering,
(c) Interviews with year one, two and three Electrical Engineering students, and with PhD students who had acted as teaching assistants for the ELECTENG 101 course,
(d) Interviews with past and present teaching and non-teaching staff,
(f) Interviews with secondary school physics teachers;
(g) Application of the Felder-Solomon Index of Learning Styles (ILS) questionnaire.
(h) Application of the MSLQ questionnaire

In addition we developed on-line tutorials to support learning in this first year (concept-rich) electrical engineering course (Collis, Rowe, & Donald, 2016). These tutorials were designed to support and further develop conceptual understanding rather than merely giving practice in the development of procedural knowledge. Students were encouraged, via a small contribution to coursework marks, to complete these tutorials and in addition to complete questionnaires which examined their learning styles (via the Felder-Soloman ILS questionnaire (Felder & Silverman, 1988)) and motivation (via the MSLQ questionnaire (Credé & Phillips, 2011; Pintrich & De Groot, 1990; Pintrich & others, 1991)). The (ethics-approved) quantitative analysis and interpretation of student performance in these tutorials and their responses to the questionnaires was enriched by interviews conducted with students, teaching assistants and lecturers. A thematic analysis was carried out on the interview transcripts. Student performance in coursework and the exam was analysed in relation to their survey responses and performance in on-line tutorials.

Eighteen first-year students, seven second-year students, one third-year student, six PhD students, two secondary school teachers and three lecturers in the department were individually interviewed. The interview questions were tailored to each type of participant and focused on how the design of ELECTENG 101 accommodated the needs of students transitioning from secondary school to first year studies, and from year one to year two engineering studies.

For student participants, the interview questions included background questions, concept understanding questions and learning questions. For example, first-year student interviews started with background questions which focused on their learning experiences of electricity in secondary school. Concept understanding questions were designed to identify what students found difficult during their study. Some electrical circuit exercises were also used to elucidate student's concept understanding levels. Pedagogical questions included probing students' perceptions of learning materials design and lecturer's teaching styles. Second year and third year student interviews also probed student's learning experiences of the ELECTENG 101 course. The PhD student interviews concentrated on identifying techniques which led to successful learning experiences and probing their tutoring experiences in the ELECTENG 101 course.

The interview questions used for lecturers were designed to probe their teaching experiences and identify what were their main concerns about student's electrical conceptual understanding.

Results

Three principal factors have emerged. Firstly, misconceptions and a poor ability to generalise knowledge into new situations - to engage in far-transfer (Perkins & Salomon, 1992). This seems to be the consequence of learning circuit understandings as isolated fragments arising from the focus on learning outcomes disconnected from the central concepts at the root of the discipline. While our analysis has identified that most student knowledge is fragmentary, some interviews revealed sound understandings underpinned by successful pedagogy with the specific teaching of knowledge-that or conceptual understanding, sequentially arranged according to conceptual progression principles (Rata, 2015). In these cases, a well-structured epistemic ascent had connected "knowledge-that" to "knowledge-how" (Winch, 2013, 2014) and led to student ability to generalise.

Secondly, and not surprisingly, student agency and engagement is a major determinant of first-year academic success. The primary driving factor associated with student motivations is the summative assessment practices which are unavoidably bound to assessable fragments of understanding. Learning linked to epistemic principles was avoided in favour of what is to be examined. While all students suffer from this those from backgrounds where pedagogy was underpinned by epistemic principles had come to realise the benefits to their understanding and had altered motivations to learning in summative laden environments.

The third factor is a local one and relates to the majority of the first-year students who have studied under a high-school qualification which is heavily constructivist in its design. A formally prescribed curriculum has been replaced by teacher (and student) choice of which topics within physics will be covered and examined. This fractures the epistemic foundation at the root of a discipline, and consequently the student has only a procedural approach to rely upon. While local in nature this was of concern to academics as there is an increasing trend toward earlier and earlier contextualised problem-based learning course design within engineering education. This social-constructivist, teacher-facilitator and student-led model of pedagogy focusses on the student, rather than the epistemic knowledge of the discipline. Introducing this type of learning too early to engineering students who do not have the epistemic foundation gives them nothing to generalise their work from or towards.

Main findings

Ready for First Year Quiz Results

Prior to beginning their studies all students are encouraged to complete a Ready for First-Year (RFFY) Quiz , the results of which inform both the lecturers and the students themselves about the student's prior preparation. This RFFY quiz comprises multi-choice questions based on years 12 and 13 of the 13-year schooling system operated in New Zealand. It has been run each year since 2011 with the results consistently showing that the students are least well prepared for the electrical subject at first year. The results obtained in 2016 and 2017 are presented in Table 1. In 2016, 511 out of a possible 892 students completed the quiz. In 2017 there was a substantial increase in the size of the first year intake (and a corresponding reduction in average entry GPA) with 588 out of 1016 students completing the quiz. The reduction in average entry GPA is clearly evident in the reduced subject averages obtained in 2017, however the relative preparedness for each of the subjects has not changed – with Electrical preparedness being by far the worst in both years.

Subject	Maximum Mark	Average Mark 2016	Average Mark 2017	Std Dev. 2016	Std Dev. 2017
Mechanics	10	6.41	6.05	2.11	2.19
Electrical	10	4.61	4.35	2.18	2.12
Biology & Chemistry	10	5.95	5.45	2.41	2.58
Maths	10	7.48	6.82	2.11	2.41
Software	10	6.68	6.31	2.11	2.31
Overall	50	27.78	25.83	6.99	7.49

Table 1 RFFY Quiz results for 2016 and 2017

In the case of the electrical questions, students were proficient on questions which tested just a single concept but struggled with any questions that required the use of multiple concepts. The conclusion we drew from these results was that such students would benefit from a first year curriculum which supported epistemic ascent with appropriately scaffolded learning activities targeting multi-concept problems.

Motivated Strategies for Learning Questionnaire (MSLQ)

In order to explore the relationship between engineering student's self-regulated learning (SRL) abilities and their academic performance, we used an online questionnaire (the Motivated Strategies for Learning Questionnaire (MSLQ)) to collect data from first-year students enrolled in ELECTENG 101. All 866 students enrolled in ELECTENG 101 in 2016 were incentivised to complete the MSLQ via a small contribution to course-work marks and the return to each student of an individual report summarising their own strategies. A total of 738 valid questionnaires were ultimately analysed. The MSLQ probes eleven SRL abilities, namely: motivation (interest), motivation (expectancy for success), confidence over taking exams, cognitive strategy (rehearsal), cognitive strategy (elaboration), cognitive strategy (organisation), metacognition, resource management (time and study space), resource management (self-effort), peer learning, and help-seeking. We performed an ANOVA test to identify the major characteristics of the students' SRL abilities, with results tagged for gender, first language, entry qualifications and future study plans. We also performed a regression analysis to find the influence (if any) of student's self-regulated learning skills on their academic performance, and it is this second analysis that has the most relevance to the theme of this paper. We found statistically significant evidence (Table 2) of impact for four SRL categories with expectancy for success, self-effort and metacognition all showing a positive impact and, surprisingly, rehearsal ability showing a negative impact. The latter result has a clear implication for curriculum design – specifically suggesting an improvement is needed in the clarity of the learning objectives and learning activities conveyed to the students.

Attribute	Coefficient	Std. Error	t-Stat	p-Value
Expectancy for Success	4.613	0.943	4.893	0.000
Self-Effort	3.178	0.794	4.003	0.000
Rehearsal	-1.820	0.671	-2.711	0.007
Metacognition	3.305	1.333	2.479	0.014
(Intercept)	32.223	5.016	6.424	0.000

Table 2 – Regression analysis of students' academic performance and SRL skills

Final examination and coursework performance

The coursework included invigilated MCQ tests and the final examination included a mixture of MCQ and long answer calculation questions. Students demonstrated proficiency on activities for which they had been trained, but struggled with far-transfer type questions and with questions that involved more than one concept. These conclusions are consistent with those found for the RFFY and suggest that improvements to the course design should probably target epistemic ascent and scaffolding of complex problems.

Felder-Solomon Index of Learning Styles (ILS) questionnaire

The Felder-Soloman ILS results were unsurprising with a significant portion of the cohort showing learning preferences for active and visual presentations. A much smaller percentage of the cohort identified with strong global learning preferences. Such students are known to be disadvantaged in many first-year engineering courses as these are often taught in a serial de-contextualised manner. The inferences we drew were to take care to always paint the big picture via literacy statements for the course overall and the major sub-sections.

Interviews and Questionnaires

Thematic analysis of the results led to the establishment of a framework of themes that included :

- Context and abstraction
- Electrical engineering knowledge

- Material object and abstract concept differentiation
- Specialised language
- Student cognitive processes
- Student agency
- Educators subject knowledge
- Educators agency and the development of their pedagogical practice

Context and abstraction

This category explored how outside prompts assist with understanding. The main prompts identified in the interview data came from three sources: experiments or practical tasks, real life examples and teacher's demonstrations. Unsurprisingly, students benefited from learning concepts by doing. Practical experiences enhanced learner understandings of concepts. Making connections between abstract concepts and concrete instances bridges the gap between learner's new and existing knowledge.

Electrical engineering knowledge

Electrical engineering knowledge is comprised of large systems of meaning made up of inferential relations between abstractions. The knowledge structure is complex and concepts are connected tightly. Specific issues identified in the interviews related to disjointed presentation of concepts, issues arising from the compartmentalised nature of the major high school qualification (NCEA), the impact on Physics of students limited numeracy skills (the ability to use Mathematics to solve problems) and the desirability of teachers building understandings using the historical background of major Physics discoveries.

Material object and abstract concept differentiation

Students reflected that if they cannot make connections of abstract concepts with physical material, it was hard for them to understand. Some teachers used vivid demonstrations to help students make the connections happen, whilst others used experiments to help students get visual and practical experiences of the concepts they studied.

Specialised language

Teachers must condense each concept using words. Words serve as signals for the concept (its symbol) and for its place in the complex system of meaning. A simple word teachers use to explain a concept can significantly influence students' understanding. One secondary teacher mentioned in his interview about the importance of consistently reinforcing correct terminology for example using the term 'electric potential' rather than the more confusing term 'voltage' just as we would not use the term 'centimeterage' instead of height.

Student cognitive processes

Meaning or know-that, is constructed via building inferential relationships between abstract concepts. Student interviews provided some specific and living examples to show when the turning point happened and students felt they truly understood a concept. Such turning points were developed by educators assisted by well-structured learning materials, which can include textbooks, lecture notes, videos, visualisations and exercises.

Student Agency

Students showed awareness of their diverse learning styles. They realized some specific kinds of learning activities, or presentation modes were particularly effective for assisting their conceptual understanding. However their response to learning situations is always mitigated by their agency - their conscious decisions about their learning behaviours. Student's responses were diverse but could be generalised into a number of approaches. Some students expressed an overt preference for shallow understanding focussed only on passing tests and exams. Some students exhibited a naïve 'espoused theory' about a preference for understanding but demonstrated a 'theory-in-use' (Argyris & Schon, 1974) which was actually focussed on passing. Some demonstrated this real preference by blaming high workloads and ever looming assessment tasks for their approach to learning and criticising lecturers when they did not teach to the test. A number of students though expressed a desire to deeply understand material and while recognising the work load issue did not let it interfere with their learning. One group of students conflate their mastery of know-how (using formula) with know-that (understanding), and, as identified by Case and Marshall (2004), this type of understanding lacks the depth of real understanding.

Teacher subject knowledge

Students talked about having physics teachers who were not trained in Physics or had insufficient subject knowledge in electricity or had knowledge that was not relevant to real world applications. While lecturers and graduate teaching assistants were seen as highly knowledgeable, lecturers were criticised by students for not making their expert knowledge comprehensible to students – significantly, this is the definition of pedagogical content knowledge.

Educators pedagogical expertise

Lecturer's teaching strategies of engaging, demonstrating, sequencing, pacing and evaluating were analyzed based on our interview and observation data. Student's levels of conceptual understanding were found to depend on lecturer's overt focus on assessment, and the clarity and logic of their explanations in relation to developing conceptual progression. Deficiencies in these areas were found to have a significant impact upon student understanding. Students made a number of references to how their school physics teachers had worked primarily to either develop understanding or to prepare students for assessment.

A problem in electrical engineering instruction identified via our interviews was a gap between the evaluation techniques used and their measure of student's actual conceptual understanding levels. Several students mentioned that even though they didn't truly understand the concepts, they still managed to solve the problems correctly. This observation is consistent with Winch's (2013) concerns about the need to embrace epistemic ascent when designing courses, to start from a sound understanding of 'first principles' and to be particularly vigilant that we don't streamline complex tasks into algorithmic procedures (Case & Gunstone, 2002).

Discussion

In order to explain the findings we theorised the thematically organised findings using a model of the knowledge-pedagogy relationship (McPhail & Rata, 2015). The purpose of the model is to show the connections between these categories:

1. The epistemic nature of electrical engineering knowledge;
2. Teacher's subject knowledge;
3. Teacher's pedagogical knowledge,
4. Specialised language; and
5. Student's epistemic identity

The application of the knowledge-pedagogy relationship model to the data from the engineering study enabled us to explore how the problem in teaching complex abstract knowledge presented itself in a particular case. Our understanding was further informed by applying the model to a second year course (Collis, Rowe, & Donald, 2017) which directly builds on this first year course. However, it is possible to generalise from this case study to a range of subjects such as technology, biochemistry, calculus in the STEM areas, but also to other non-STEM academic subjects, including music, languages, and history. The findings have sufficient generic principles concerning how curriculum and pedagogy are integrated to provide teachers with the means to select, organise, and deliver content specific to their courses in ways that will lead to student conceptual understanding. In this way, the findings can be used both for course design and for the analysis of that design.

Our data analysis re-affirms Hattie's (2012, 2014) conclusion of the importance of making the learning process visible to students. Furthermore our analysis has led us toward a course which begins with the identification of student identity – and the development of new lenses through which we want a student to view our domain. This is then expressed in learning outcomes centred on abstract understandings rather than content. Through a well-planned epistemic ascent that is rooted in first principles, these are unfolded into specific success criteria and learning activities. Ultimately these return to the overarching identity and course goal that expresses the new lens through which we want a student to view our domain

A complicating feature related to development of know-that knowledge is just how one should best scaffold this process to minimize cognitive overload. In this regard we are informed by the process of scaffolding where relational complexity is reduced by progressively chunking concepts into more and more semantically dense concepts (McCredden, O'Shea, Terrill, & Reidsema, 2016).

The key aspects we have identified from the data can be broken down into three groups. The first two (1-2 below) relate to the establishment of conceptual knowledge (i.e. knowledge "that") while the next two (3-4 below) relate to procedural knowledge (i.e. knowledge "how"). The final aspect (5 below) relates to "choreographing" an appropriate flow between development of meaning via conceptual knowledge and development of skill via contextually-based procedural knowledge to ensure the primacy of the epistemic ascent (through a hierarchy of inferentially related concepts).

1. An overarching goal relating to student identity for the course, or for each major section.
2. Clear identification of:
    a. The first principles /core concepts of the domain which must be understood
    b. The relationship (i.e. linkages) between these concepts
    c. The subset of all the concepts which experts want novice learners to understand and which will form the learning objectives for the course.
    d. An appropriate hierarchy for these concepts which would facilitate epistemic ascent
    e. The development of a concept map of the key concepts and their linkages may prove useful to use with students in this process.
3. For each concept related learning objective, establish a set of contextualised learning activities by which the students may measure the success of the learning (and ideally compare their level of success and their learning progress with that of their peers).
4. For each learning activity identify the scaffolding that will be needed to achieve manageable levels of relational complexity, ideally ensuring students hold no more than four concepts in working memory at any one time. These activities should be

small and frequent to encourage students to study for mastery rather than study for the test/exam. Prompt marking and formative feedback which offers strategies for improved learning are essential.

5. Establish a plan to use direct instruction to flow between the development of conceptual and procedural knowledge, ensuring the primacy of the conceptual development so that learners emerge with “generalisable” integrated conceptual understanding permitting “far transfer” rather than just fragmentary procedural knowledge limited to familiar contexts.

It is traditional to train high school teachers in educational theory to assist them in developing pedagogical content knowledge (PCK) - “the ways of representing and formulating the subject that make it comprehensible to others”‘ (Shulman, 1986, p. 9). It is thus accepted at school level that curriculum and pedagogy are inextricably linked, so that it would be inappropriate to consider one without the other. However, that linkage isn’t so well known amongst all tertiary lecturers and examples abound of curriculum designs focussed solely on content, with learning outcomes written in terms of simple algorithmic procedures amenable to drill and practice and easy assessment, rather than complex tasks developing integrated conceptual understanding. Thus the first original contribution of our research is to look at course design in such a way that the basics of PCK are automatically addressed.

However we aim for substantially more than that. It is already known that concept maps prepared for the same subject by expert scientists and by teachers of science (trained in PCK) differ substantially, with those of the scientists reported to be more flexible and those of the teacher more rigid – allegedly because of high school curricular constraints. This has implications for tertiary teaching in that a straight PCK approach may be too limited. For this reason our analysis gives primacy to facilitating epistemic ascent and encourages that by direct instruction which appropriately guides the flow of instruction from abstract conceptual understanding, moves to authentic contextual activities and returns ultimately to wrap up the learning experiences in terms of enhanced abstract understandings.

Conclusions

While the project is still a work in progress we have identified several key features to be considered in the development of an engineering course which is embedded in a deeper understanding of the inferential connections between propositional and procedural knowledge (Wheelahan, 2010). Of most significance is the requirement for course designers to begin earlier than they begin now with a “first principles” interrogation of the key concepts (McPhail & Rata, 2015). Our insights on course design to date are built around three key mantras:

(1) What you teach must be ordered by first principles

(2) What you teach must be consistently linked back to first principles

(3) When connecting ideas to examples, reinforce general principles not contextual ones.

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Peer Evaluation of Teamwork Activities in Undergraduate Engineering Design

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SESSION C3: Integration of teaching and research in the engineering training process

CONTEXT This paper reports that a formal peer evaluation system combined with teamwork development activities may be an option to facilitate professional skill development in undergraduate students. This paper outlines the implementation of an online, peer evaluation system designed to facilitate feedback, mark moderation and student reflection on teamwork. This system is also helpful in discouraging poor team conduct by making students accountable to their teammates for the quality and quantity of work that they contribute and their communication in team-based assessments. Self-evaluation is also used to encourage reflective practice and highlight any differences in perceived contributions.

PURPOSE The objective of this research is to assess student attitudes towards the use of an anonymous, online peer evaluation tool (CATME) and teamwork and professional skill development in a second year engineering design unit, where team-based assessments make up a significant portion of the overall grade.

APPROACH Multimedia resources and team meeting activities were developed to introduce CATME to students and to support their use of the tool throughout the semester. An anonymous online survey was administered at the end of the semester to assess student attitudes towards the use of a formal peer evaluation system and formal team development activities. Students were also asked to rate their level of satisfaction with their team and how the activities within the unit contributed to the development of teamwork and interpersonal skills. An analysis of open ended written comments submitted as part of the survey was used to provide additional insight into student attitudes and perceptions.

RESULTS Findings from the online survey show that on average, respondents agreed that they should evaluate the contribution of their peers, that they felt comfortable knowing their marks would be moderated based on peer evaluation and that a formal peer evaluation system was a fair way to moderate team marks. By the end of the unit, students agreed that their interpersonal communication, ability to resolve conflicts, management skills and accountability had improved. There was also agreement that the formal team development activities were helpful in facilitating teamwork in aspects such as communication and project planning. On average, students indicated that they would rather work in teamwork activities and team projects in which there is a formal peer evaluation system. Open ended written comments indicated that students appreciated having a formal system which enforces individual accountability, and through which they could report on the contribution of individual team members, knowing that they were supported by a fair process of mark moderation.

CONCLUSIONS An online peer evaluation system was successfully implemented in a second year engineering design unit; its use was accompanied by various multimedia resources and formal team development activities. Survey results suggest that students responded favourably to this system, and as a result it will be deployed in more engineering design units in the coming years.

KEYWORDS CATME; peer evaluation; formative assessment; reflective practice

Introduction

Team-based assessments can help students to develop the knowledge, skills and abilities (KSAs) that increase students' graduate employability. Stevens and Campion (1994) outline a set of KSA requirements for teamwork that include: conflict resolution, collaborative problem solving, communication, goal setting, planning and coordination. These professional teamwork and communication skills are required in graduate engineers (Engineers Australia 2011) and are highly regarded by graduate employers (May and Strong, 2011). However, students working in teams can encounter various teamwork issues, a common cause of which is social loafing, a phenomenon where individuals exert less effort when working in a group or team (Simms and Nichols, 2014). Teamwork issues can manifest as breakdowns in communication, poor decision making and task and relational conflict (Borrego et al. 2013). When left unresolved and without instructor support, these issues can negatively affect students' satisfaction with teamwork. Oakley et al. (2007) surveyed over six thousand students in Engineering and found that student satisfaction in teams is significantly affected by the presence of 'slackers' and the level of instructor guidance on teamwork. This finding echoes that of Bolton (1999), who found higher satisfaction rates when students were provided with additional team training and instructor support.

Peer evaluation (PE) has been suggested as an effective option for mitigating social loafing and reducing the occurrence of conflict (Albanese and Van Fleet, 1985; Chen and Lou, 2004; Pfaff and Huddleston, 2003). PE enables instructors to manage and moderate teamwork by allowing students to evaluate themselves and their peers in aspects of teamwork such as technical ability and team dynamics. PE can be used to encourage effective teamwork by rewarding effective team members and discouraging poor teamwork by adjusting individual grades to reflect teamwork contribution (Ohland et al., 2012; Brutus and Donia, 2010; Kaufman et al., 2000; Brown, 1995). There is also a growing body of research that suggests PE as an effective means of developing teamwork KSAs (Brutus and Donia, 2010; Willey and Gardner, 2007; Loughry et al., 2014). PE may be used to improve students' teamwork satisfaction in two ways: 1) rewarding effective team members and associating poor teamwork with negative consequences on student grades (mark moderation) and 2) facilitating the development of teamwork KSAs through feedback and reflection.

There are various online peer evaluation platforms; some examples include: CATME (Ohland et al., 2012); SPARKPLUS (Willey and Gardner, 2010) and WebPA (Loddington et al., 2009). CATME (Comprehensive Assessment of Team Member Effectiveness) is a platform that can be used for both mark moderation and for facilitating the development of teamwork KSAs through feedback and reflection. CATME Peer Evaluation is used in this study owing to its Behaviourally Anchored Rating Scale (BARS) evaluation rubric (Ohland et al., 2012) and the simple interface. CATME assesses team member effectiveness in five main categories: 1) Contributing to the team's work; 2) Interacting with teammates; 3) Keeping the team on track; 4) Expecting quality; 5) Having relevant knowledge skills and abilities. The CATME peer evaluation survey requires students to rate themselves and their team members on these aspects of teamwork according the BARS evaluation rubric. CATME peer evaluation facilitates mark moderation of team projects using an adjustment factor, which is computed as:

$$\text{Adj Factor} = \frac{\textit{average rating of the student}}{\textit{overall average rating for the team}}$$

Mark moderation involves multiplying the adjustment factor with the mark received by the team for the assessment to generate an individual student mark. High-performing team members are rewarded while poor-performing or non-contributing members may be scaled down. This process helps instructors moderate teamwork so that students receive an individual mark that reflects their contributions to the team.

CATME peer evaluation was implemented in a second year Engineering Design unit at a large university in Australia. Students also participated in formal team development activities to supplement the peer evaluation surveys. The aims of this study are to investigate student attitudes towards using a formal peer evaluation system and to examine the effect of peer evaluation and team development activities on students' teamwork satisfaction and their perception of learning outcomes.

Theoretical Perspective

The approach to facilitating professional skills development using peer evaluation and team development activities is largely informed by Schön's (1983) theory of reflective practice and Sadler's (1989) theory of formative assessment. In Schön's work, reflection is described as a means by which a practitioner, through experience, builds upon their knowledge base to reach a better understanding of their actions and behaviours and inform future actions and decision-making. Loughran (2002) adds to Schön's theory by asserting that experience alone does not lead to learning and that more essentially it is the reflection on experience that can enhance learning. That is, teamwork alone may not help students develop professional skills; undergraduate students in particular need opportunities to reflect on teamwork experiences, emotions and outcomes as a way to draw insight and understanding of teamwork to inform future actions.

Formative assessment, where feedback is the main mechanism for learning, can facilitate reflective thinking. In the context of teamwork, Sadler's prescription of the three conditions for feedback are: 1) an understanding of what constitutes effective teamwork; 2) an ability to evaluate team member effectiveness against a standard and 3) the tools and knowledge to improve performance. The first and second points outlined by Sadler are satisfied by the BARS in CATME peer evaluation and the third condition is met with the team development activities embedded in the unit design.

Peer evaluation is a practice through which students have the opportunity to regularly reflect on teamwork experiences and interpersonal interactions. When used formatively, it can enable students to gain knowledge of the standards (building their knowledge base) for good teamwork and develop students' ability to evaluate the performance of their peers and themselves. Used summatively (mark moderation), peer evaluation can elicit from students a sense of individual accountability for teamwork (Kaufman et al., 2000; Brown, 1995). Finally, the feedback process is completed when students engage in self and team reflection which is facilitated by team development activities. Schön and Sadler's theories inform the pedagogical practices described in this study and the existing literature suggests that peer evaluation can improve student satisfaction by discouraging poor teamwork behaviour while team development activities facilitate effective teamwork.

Context

In semester one of 2015, a trial was conducted with a peer evaluation tool in a second year Mechanical, Aerospace and Mechatronics Engineering design unit with 285 student enrolments. The major continuous assessment in this unit involved students working in teams of four to five to design, build and test an autonomous device to navigate a track and deliver a payload (Smith, 2008). Heterogeneous teams were formed by the instructor with the intent to create a good mix of male/female students, cultural diversity, academic performance, international/domestic status and hands-on building experience (Felder and Brent, 2001). Students remained in their assigned teams for the duration of the major team project and semester (12 weeks). Teams made a preliminary submission for their design in week five, competed with other teams in a campus competition in week nine and submitted a final team report in week twelve. Students completed two rounds of CATME peer evaluation surveys to evaluate teamwork - once after the preliminary submission and once after the final report submission which included consideration of the campus competition. The instructor requested that all students provide at least one sentence for each team member (including themselves) to justify their ratings in the 'Comments to the Instructor' text field at the end of the survey. Students were warned that individual marks (up to 10%) could be deducted for failure to provide meaningful written comments on aspects of teamwork. Students were informed that they would receive individual marks for the two major project submissions based on the adjustment factor generated from the peer evaluation system, subject to moderation and manual changes made by the instructor. The instructor performed moderation based on the rating patterns within the team and written comments from each student about their team. Students' individual marks could be scaled up by a maximum of 10% of their team's mark, but there was no limit on the downside scaling. Students could not receive more than full marks for any project submission.

To support effective teamwork, scheduled class time was allocated for students to complete team development activities at four scheduled intervals throughout the semester. Students completed an icebreaker activity in week one, a project planning meeting in week three, a teamwork reflection meeting in week five and a peer evaluation feedback meeting in week six. The instructor provided students with agenda and meeting minutes templates to guide students in practicing effective management and communication. Teams were also provided with a short video (four minutes) introducing them to the CATME peer evaluation system. Students were required to practice evaluating a hypothetical team before evaluating their real team members in the first round. The system provided feedback to students on the accuracy of their ratings of the hypothetical team members which helped students to understand the BARS.

Method

At the end of the semester, students were asked to complete an online, anonymous survey to capture their attitudes toward the peer evaluation process and team development activities. Students responded to twenty-five questions on various aspects of teamwork in the unit including: mark moderation; peer evaluation; teamwork satisfaction; professional skills development and team development activities. Responses were recorded on a seven-point Likert scale between strongly disagree (-3) and strongly agree (+3) for all but one question which measured whether students felt that the mark moderations were too small (-3) or too large (+3). As part of the survey, students were also asked to provide written comments on their experience with using peer evaluations in the unit. The survey data was analysed with descriptive statistics (proportions, means and variances) and themes were uncovered in the written comments with simple qualitative coding. Ethics approval for this research was sought and granted from the university's human research ethics committee (project number: CF15/2901 - 2015001197).

Results & Discussion

The survey received a response rate of 24% (67 students). Demographic data such as gender, ethnicity and age were not recorded. This was a limitation in this study as there was little indication of whether the respondents were proportionately representative of the cohort. A histogram of the responses for each question is represented by shaded boxes where the darkness of shade indicates the number of counts for each position on the Likert scale (Figure 1). The distribution of responses for each question was displayed in this manner to simultaneously illustrate the skewness in the responses, the mean response, and to provide a good indication of the variance in the Likert scale ratings. Ratings adjacent to neutral (-1 and +1) are considered as relatively neutral, ratings between 1 and 2 are considered to be moderate agreement, and ratings of +2 and +3 are considered as strong agreement.

Variance in Responses

Students tended to be in agreement with the statements provided, with their responses exhibiting a negative skew (Figure 1). This could indicate that students truly felt positively about teamwork, peer evaluation and team development activities, though it is also possible that the responses, like many others measured on Likert scales, tend to be negatively skewed (Peterson and Wilson, 1992). The small variance in questions 1 - *severity of mark moderation* (variance = 1.5), 21 - *helped my team get to know each other* (variance = 1.3), and 22 - *helped my team to establish lines of communication* (variance = 0.9) indicates that there is a strong consensus in the cohort that the mark moderations were neither too small or too large and that the team development activities facilitated effective communication early in the semester.

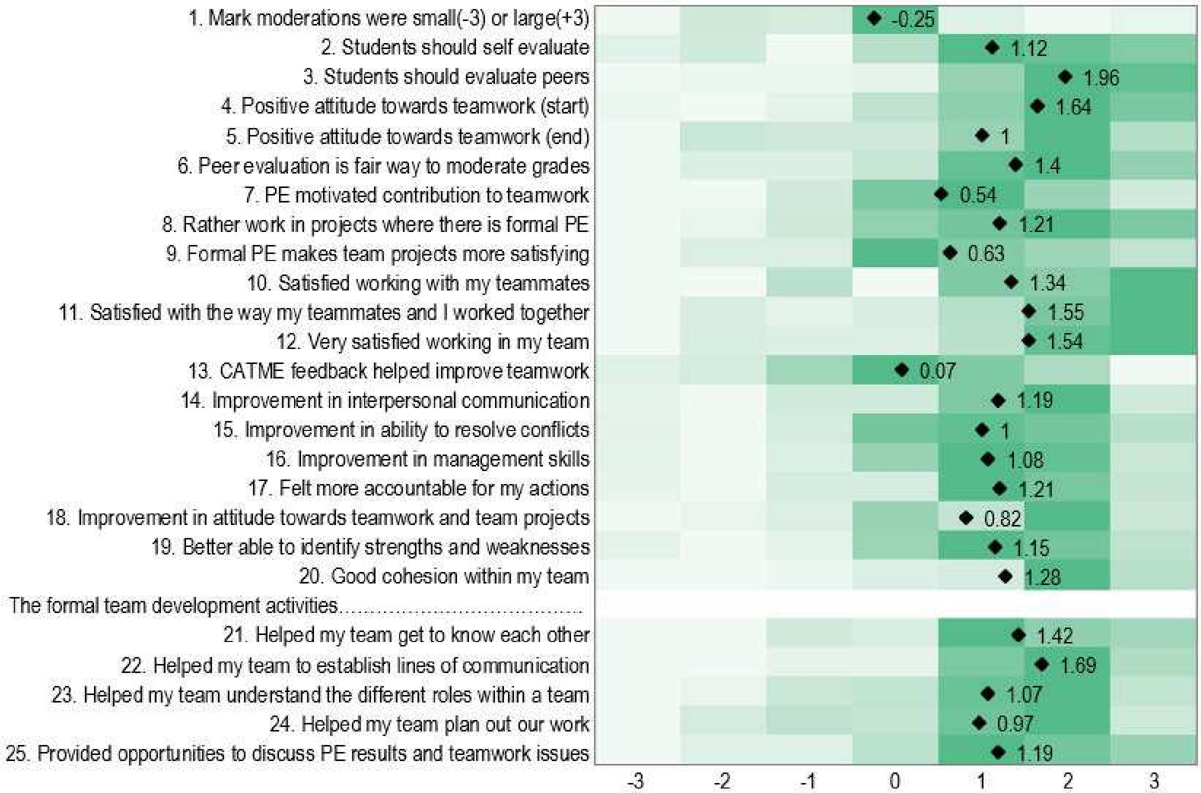

Figure 1: The average response (diamond) on a seven point Likert scale from strongly disagree (-3) to strongly agree (+3) unless otherwise specified. The data labels for the average is displayed numerically next to each diamond. The shaded region represents a histogram of the number of responses for each question; darker regions indicate a higher count of responses.

The variance was largest in question 2 - *students should self-evaluate* (variance = 2.7); the cohort was divided on the idea that students should self-evaluate their contributions to teamwork. There was greater consensus that *students should evaluate their peers on teamwork contribution* (variance = 1.1). This likely indicates that a considerable portion of the class failed to appreciate the importance of self-appraisal in comparison with peer-appraisal. In a cohort of undergraduate engineering students, this is not surprising; it’s likely that these second-year students are yet to develop the reflective mindset that would allow them to appreciate the significance of self-evaluation. Repeated practice with self and peer evaluation may help students to develop a reflective mindset over time. The next largest variances were seen in questions 10 – *I was satisfied working with my teammates* (variance = 2.7) and 18 - *I felt that my attitude towards teamwork and team-based projects had improved* (variance = 2.7). Both variances indicate that the cohort was widely mixed with good and poor teamwork experiences throughout the semester. Again, this comes as no surprise; for many students this unit was the first in which they engaged significantly in teamwork. The combination of heterogeneous instructor-formed teams and an above average workload meant that each student’s experience of teamwork depended heavily on how well they got along with their teammates. Inevitably, a small number of teams encountered conflict and discontent, leading to a relatively large variance in teamwork satisfaction and shift in teamwork attitudes.

Professional Skill Development

The survey data indicates that students on average felt they had improved in several professional skill categories, namely interpersonal communication, ability to resolve conflicts, management skills, accountability and ability to identify strengths and weaknesses (Q14-17, 19). A large proportion of the cohort responded with the second highest (+2) and highest (+3) agreement rating to these questions (Table 1).

Table 1: Percentage of the class in strong agreement for questions 14-17 and 19 (responses in the second-highest or highest agreement rating).

Question: At the end of the current unit...	Percentage
...I felt that my interpersonal communication had improved.	51%
...I felt that my ability to resolve conflicts within the team had improved.	38%
...I felt that my management skills had improved.	41%
...I felt more accountable for my actions.	45%
...I was better able to identify my strengths and weaknesses.	42%

Just over half the class indicated strong agreement that their interpersonal skills had improved; smaller though nonetheless considerable portions of the class indicated strong agreement that their management skills, ability to resolve conflicts and ability to identify own strengths and weaknesses had improved. It is likely that PE and formal team development activities played a role in these improvements; this could be confirmed by conducting a controlled study.

Accountability

Nearly half the class indicated strong agreement that at the end of the unit they felt more accountable for their actions (Table 1). Individual student marks were generated by adjusting the team's mark for project submissions based on students' peer evaluation adjustment factors. Students were informed about this practice at the beginning of the semester, which helped to ensure that students were fully aware that the marks they receive would be affected by their team contributions and team member effectiveness. It is likely that this practice of mark moderation played a significant role in establishing individual accountability amongst team members for their actions and behaviours in the team. In the first round of peer evaluation, adjustment factors were moderated by the instructor so that students received slightly higher adjustment factors than the raw values generated by CATME. This practice served as an initial warning to poor performing or non-contributing team members to improve their performance. In the second round of peer evaluation, the instructor was more critical with moderation of individual marks; one student even received an adjustment factor of zero (this student failed to engage with the team and project), meaning that they received an individual mark of zero for the final project submission.

Written Comments

Best aspects of the peer evaluation system

Analysis of the written comments regarding the best aspects of peer evaluation revealed that *fairness/accountability* and *feedback* were the prevailing themes. Students appreciated that there was a formal moderation process in place to reflect individual contributions to teamwork and that this process held team members accountable (22 comments). A notable comment that reflects this sentiment was: *"If you have to do more of the work than team members who are lazy/don't take any initiative, you get rewarded. This means that if your teammates don't carry their weight then your personal mark is not as badly affected."*

Two students noted that it is also a good way to anonymously communicate how they felt about their team members. Anonymity was considered an important scaffold for second year students who were relatively inexperienced at reflecting on teamwork and exchanging feedback with their teammates. In cases where serious conflicts were detected, teams were required to hold an instructor-moderated team meeting to resolve their issues. Students were ultimately required to confront teamwork issues with their team; they could not simply remain sheltered by the anonymity of the PE system. Students reported that it was insightful to receive feedback on what their teammates thought about them and that this feedback helped them improve (11 comments). One such comment was: *"CATME allowed each person in the group to see what the group thought about them, and which aspects of teamwork they were good/bad at".* The comments concerning feedback indicate that some students were engaging in reflection and that the CATME feedback system gave additional insight for students to understand how they performed relative to the average of their team.

Suggestions for how the peer evaluation system could be improved

Teamwork moderation and *rating scale/rubric* were the prevailing themes that emerged from students' comments on how the peer evaluation system could be improved. This cohort of Engineering students described the rubric and rating scale as ambiguous; subjective and vague; they suggested a more discrete and quantitative measurement of teamwork contribution in place of the behaviourally-anchored and descriptive rubric, which they found overly generic (5 comments). It is quite common for engineering students to demonstrate a preference for quantitative reasoning (Trevelyan, 2014) and this mindset is evident in students' suggestions; one student suggested [sic]: *"Add an estimated hours worked, even the peer evaluation is useless if the person filling it out doesn't want to be a snitch and rat out team members cause it's not worth the hassle"*. Students' comments on the lack of quantitative measurements of teamwork contribution indicates a lack of appreciation for those aspects of teamwork that are difficult to measure quantitatively (motivating the team; making sure teammates stay informed; caring that the team does outstanding work, etc). It also indicates that students tend to show disproportionate preference for technical ability and effort in labour as a measure of effective teamwork. Repeated practice of peer evaluation may be a good strategy to change engineering students' quantitative bias over time.

Some students were critical of the mark moderation process and the reliability of ratings (10 comments); one student wrote: *"My suggestion would be that the comments at the end of the section have a greater weight in the deciding how to moderate marks as there will always be some things that the questions would not be able to cover"*. Another student felt that it was harsh for a team member to be *"marked down purely because other members went above and beyond what should be expected."* and suggested that team members *"should not be scaled down simply because they may have been outperformed"*. The instructor shall take these comments into consideration for future implementations of CATME peer evaluation.

Future Work

This research is ongoing; the next iteration will report on a controlled intervention using peer evaluation and team development activities. Findings from this controlled study shall enable more insightful comparisons with the literature on the effects of PE combined with team development activities on students' development of professional skills.

Conclusions

A formal peer evaluation system and team development activities were implemented in a team-based second year Engineering design subject. Students' perceived professional skill development and their attitudes toward formal peer evaluation and team development activities were investigated with an anonymous online survey. The findings indicate that students generally recognised the benefits of both peer evaluation and team development activities, namely in making teamwork 'fairer'; holding team members accountable; improving in teamwork KSAs; identifying strengths and weaknesses; facilitating team communications; project planning and opportunities for teamwork reflection. Following this positive response, peer evaluation has been widely implemented across the institution, with the current yearly number of unique student users estimated to be over 10,000.

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Redeveloping an introductory course in microcontrollers through the lens of educational theory

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT

This paper reports on the redevelopment of a poorly performing introductory theory course on microcontrollers through the application of educational theory. The course begins with seven weeks on digital electronics then four weeks on microcontrollers. For a number of years the microcontroller section of the course has had low achievement and negative feedback from students as well as from staff in subsequent project-based design courses.

PURPOSE

The aims for the redevelopment were to 1) improve student understanding of microcontroller based systems and 2) improve the student learning experience - a key faculty goal.

APPROACH

A period of discovery was undertaken in 2015 by observing both this theory course and the subsequent project-based design course by attending lectures and laboratories, reviewing course materials and results, and taking part in discussions with students, staff and teaching assistants. This revealed low level and poorly linked understandings. A full redevelopment of this part of the course was undertaken with reference to educational theory and best practices in teaching. The redevelopment brings together two knowledge realms; the first is the engineering knowledge of embedded systems and the second is pedagogy. The synergy of the two into one rich knowledge base is Pedagogical Content Knowledge (PCK), a requisite for making subject matter "comprehensible to others" (Shulman, 1986, p. 9).

RESULTS

Course evaluations show a marked increase in student satisfaction ratings with the course overall rising from unsatisfactory to above average in university wide rankings. Student behaviour and results in the examination reveal positive change and feedback from students in the subsequent design course reveal increased engagement and understanding.

CONCLUSIONS

Bringing together engineering knowledge with theory and best practices of education allowed the diverse requirements of student understanding, engineering theory and department goals to efficiently converge toward a best fit for a course. The results also indicate the benefits of grounding trials of new teaching and learning strategies (e.g. a new software tool) in theory and practice so as to make a fairer assessment of their potential in benefitting students.

KEYWORDS

Microcontrollers, learning outcomes, Pedagogical Content Knowledge, epistemic ascent, Technological Pedagogical Content Knowledge

Introduction

Fundamentals of Computer Engineering is a first semester, second year theory course for all Electrical and Electronic, Computer Systems, and Software Engineering students at the University of Auckland. The course begins with seven weeks on digital electronics and Field Programmable Gate Arrays (FPGAs) followed by four weeks on microcontrollers.

The microcontroller section has four weeks of lectures, four voluntary tutorials, an assignment and a single two-hour laboratory. In the final exam students are required to answer five of six questions; four relate to the digital/FPGA content and two relate to microcontrollers. In 2016 86% of the students chose the four digital questions before choosing one of the microcontroller questions to answer. The average grades for students were 82% for the digital questions and 59% for the microcontroller questions. As well as the low achievement by students in the exam the microcontroller section of the course has received very low evaluations in course surveys and negative comments about students' abilities and understandings by teaching staff in subsequent project-based design courses.

Learning issues identified during observations of students and discussions with them in this and other courses revealed a reliance on procedural knowledge or 'know-how' with inadequate conceptual understanding or 'know-that'(Winch, 2014), this led to students inability to apply their knowledge in new situations. Students also showed preference for just-in-time studying for assignments and tests, and avoidance of non-assessed learning tasks. Examining the course structure revealed a series of isolated topics, with little progression from underpinning concepts, and only one laboratory session for working with hardware; hands on experience is recognised as the only way learners can fully appreciate the nuances of embedded systems (Koopman et al., 2005).

The first author who redeveloped the course is undertaking PhD research in student understandings within the department. He is an engineer with 40 years' experience in various electronics industries, secondary school teaching and teacher education.

Pedagogy

In this section pedagogy underpinning the redevelopment is discussed, in the subsequent section there is an explanation of how pedagogy was applied within the course.

While there is much quality literature for tertiary educators e.g. Ambrose et al. (2010), Biggs and Tang (2011), there is a significant body of educational literature in school education that tertiary educators may be less familiar with which can also enrich their practice. This literature includes one well researched analysis of pedagogy by Professor John Hattie whose research team synthesized understandings from over 900 meta analyses (representing over 50,000 research studies) to identify what works best for student achievement (Hattie, 2012, 2014). They concluded the most powerful impacts on learning were from educators who are proficient in their subject knowledge and passionately engaged with teaching and learning. Passionately engaged means: being aware of students' pre-existing understandings, establishing learning outcomes and specific criteria against which both educators and students use to monitor performance, providing formative feedback, structuring learning sequences that bring together single ideas into complex constructs, creating opportunities for learners to actively construct understanding and providing safe places for risk taking and learning from failure (Hattie, 2014). Over and above best practices their research identified characteristics of expert educators. Expert educators are vigilant about evaluating their impact on student learning. From careful evaluation of student results experts develop the ability to adapt to what has the most impact on student understanding, this gives the expert the ability to more accurately anticipate learning issues.

Three questions that underpin student success

Student success begins with making the learning process visible to students and not something that only the educator knows about (Hattie, 2014). This visibility comes about when students are taught to ask and reflect on three questions about their learning: “Where am I going? How am I going? Where to next?” (Hattie & Timperley, 2007, p. 86).

The first question includes the overarching goal and the outcomes for their learning. In education the overarching goal is ‘literacy’, e.g. scientific literacy or mathematical literacy (numeracy). A common complaint in engineering is that student’s ‘math is not good enough’, even though they can carry out complex mathematical procedures. Numeracy however “involves students recognising and understanding the role of mathematics in the world and having the dispositions and capacities to use mathematical knowledge and skills purposefully” (ACARA, 2017). Writing a literacy focussed goal for a subject and keeping it in front of students helps them to know the answer to ‘where am I going?’

To become literate the ‘I know where I am going’ learner needs learning outcomes that give structure to their learning path. Bloom’s Taxonomy (Krathwohl, 2002) provides six levels of cognitive skill for student tasks: remembering (lowest), understanding, applying, analysing, synthesizing and evaluating (highest), which are useful starters for learning outcomes. Educators often express learning outcomes in concrete terms i.e. as skills or abilities. This reflects the common practice of educational writers which is to discourage the direct use of cognitive skill levels such as ‘understand’ when writing learning outcomes, instead recommending the use of action verbs (Ambrose et al., 2010; Biggs & Tang, 2011). Using action verbs however leads educators to directly include content and context in learning outcomes such as those given as examples by Ambrose and Biggs and Tang. This overt focus on content has led to tertiary education being accused of “content tyranny” (Prince, 2004, p. 229). The outcomes of academic learning however are not content, they are generalisations or abstract understanding - “a description of the world that does not consist in doing the activity alone” (Laurillard, 2002, p. 19). Learning outcomes then would be best to state the abstract concepts that we want a student to understand at course completion. This is reflected within school education, where the movement has been away from writing content and context in learning outcomes (Clarke, 2005, 2008; Hattie, 2012).

The second question students need to learn to ask is ‘how am I going?’ To directly help students with this question, learning outcomes are unpacked into specific skill or knowledge statements called ‘success criteria’ which both educators and students can measure progress against (Clarke, 2005, 2008; Hattie, 2012). Success criteria make use of action verbs, so they appear in a form which many educators would describe as the same as their current learning outcomes. Using this fuller three-step process of literacy goal to learning outcomes to success criteria however encourages educators to bring deep abstract understandings to the fore of learning rather than content related actions which focus students on an appearance of understanding, something we should never do (Winch, 2013). We do this however with content focussed learning in physics and engineering where complex tasks are regularly streamlined into algorithmic procedures (Case & Gunstone, 2002) in order for students to undertake drill and practice with them. While practice is critical for competence, without relating it back to a deep understanding goal, it has long been recognised as “an inadequate basis for later learning” (Brownell, 1935, p. 6). In this way a student’s response to the question about how well they are going can be framed in terms of understanding rather any ability to use a formula.

The third question learners need to ask is ‘where to next?’ This relates not to the next step in the learning sequence but to metacognition - which means the student is able to recognise deficiencies in their understanding and choose paths about how to solve them. Ownership of learning is something that we desire of students in their project work; however it is also something we can encourage in all courses. To do this we need to regularly reinforce goals, learning outcomes and success criteria with students (Clarke, 2005, 2008; Hattie, 2012), in this way students become purposefully engaged with the real goal of their education, the development of academic or abstract understanding.

With dependent learners there needs to be an explicit training and a gradual handing over of responsibility for learning. To achieve this educators can rephrase the three questions for these learners as: Which learning outcome does this task relate to? How do you relate what you are doing to the learning outcome? What questions do you still have about your own understanding and how will you resolve them?

Formative feedback

Feedback directly relates to the second question and it is through feedback on tasks that student learning occurs (Hattie, 2014). Feedback comes in many forms, from ineffectual praise to in/correct results to more powerful formative forms. While at times helpful the confirmation of in/correctness does not always make visible what is required for a student to develop. Formative feedback involves giving directions for students to pursue or making strategies explicit or more powerfully from comparative effects to other students or the provision of less explicit cues. Feedback needs to be explicitly linked to learning outcomes so that students begin to monitor and self-regulate their own learning. Feedback must also be critically timed in relation to student effort; this for instance can make computer-assisted feedback powerful (Hattie & Timperley, 2007). A highly useful tool for deciding what level of feedback to give students is the SOLO (Structure of the Observed Learning Outcome) Taxonomy (Biggs & Collis, 1982). SOLO helps educators recognise at which of five conceptual levels a student is working. Pre-structural means a student has no knowledge of the content; uni-structural, they have a single fragment; multi-structural, they have unconnected fragments of knowledge; relational means linked (conceptual) understandings - they can express the interactions between various parts; and extended-abstract, a student is able to abstract understandings into new contexts. Feedback is best focussed on the level the student is operating in relation to where they need to be.

Subject hierarchy / epistemic ascent

Another key aspect of the second question is the awareness that both educators and students need of a subject, that the knowledge within it has epistemic ascent – it is tiered and exists in a hierarchy (Winch, 2013). This requires that a learner builds successive understandings or fits new knowledge correctly into the existing hierarchy. This is an important recognition of and requirement for an educators own deep understandings of their subject, as without this proficiency any hierarchy becomes elusive making it impossible to adequately identify success criteria.

It is crucial to recognise that higher up the epistemic hierarchy terms become more semantically dense or terse as they encapsulate more and more meaning. ‘Timer’ and ‘ADC’ are examples of semantically dense terms. Often educators’ understandings are highly tacit and what we once had to learn to understand a term has long been condensed into it. Pedagogy involves fleshing out a subject’s hierarchy and density and then building a hierarchy for learner progress. One aspect of formal teacher education involves this unpacking of knowledge; however this is not an aspect of most tertiary lecturers’ backgrounds. Where one aspect of understanding condenses another, we need to be aware that not making the linked hierarchy visible can lead students to build isolated clusters of knowledge which compromise their conceptual development (Winch, 2013). This was noted in a digital electronics module of a course when a student remarked “it’s like you had to be a hobbyist already to understand it”.

Scaffolding

This is the term we use to plan the conceptual chunks (not procedural steps) in the epistemic hierarchy; Vygotsky developed the theory of the zone of proximal development (ZPD) which has been used to inform pedagogy around scaffolding (Chaiklin, 2003). When scaffolding learning there are concepts that students can learn with no external support, there are those which students need external support to learn and there are concepts they are not ready for. In the latter case further work is needed in unpacking the hierarchy and the development of more intermediate conceptual chunks. The work in threshold concepts (Meyer & Land, 2003) particularly in our domain of electronics (Scott & Harlow, 2012) highlights the significance of concepts which students are not ready for. An educators practice involves planning a manageable hierarchy of conceptual chunks and then evaluating the effectiveness of our efforts in terms of students' subsequent understanding.

Direct instruction

A constraint in tertiary education is the large cohort. Lecturing to large classes often attracts criticism as being transmission of information to a passive audience. Direct instruction is the method that incorporates lecturing, but it does not assume that learners are passive. Direct instruction is most powerful when centred on learning outcomes, has a 'hook' for student's attention, when concepts are fully explained, practice is guided, and there is a way to check understanding through independent practice in a new context (Hattie, 2012, 2014). In response to the negativity around lecturing student-directed models of learning (inquiry, social-constructivist, problem-based) are increasing in popularity. These however rely on the student discovering the knowledge needed to solve a problem, which will only work when learners already have satisfactory prior knowledge and understanding (Kirschner, Sweller, & Clark, 2006).

Student dispositions toward learning

One of the most significant and negative impacts on question three for students (where to next) is the role that summative assessment plays in credentialing students, lecturers and institutions alike. Students driven by heavy workloads and constant time pressure (Case & Gunstone, 2002) recognise the value of understanding in their learning but shortcut it, and educators focussed on manageable assessments develop isolated tasks that encourage shallow and fragmented learning. Our prior research focussed on developing conceptual tutorials (Collis, Rowe, & Donald, 2016) about which one student remarked *"I could have answered the test questions without having known this, but knowing it is just better"*. We need to change student perception about deep learning from being 'better' to that of being 'essential' so that they change their disposition toward learning and then their agency - their conscious choices around learning behaviours. One effective method is to be insistent about learning, to move beyond "this would make a good exam question" to focussing students' on learning outcomes and graduate attributes in spite of any looming test or exam. This is one aspect that Hattie (2014) says differentiates the expert educator.

Educational technology

Leveraging off modern technology can increase the power of teaching around question two, how am I going? Benefits however are only realised when the technology is integrated using sound pedagogy (Laurillard, 2002). The expertise and capacity to teach in a particular subject area using learning technologies has been called Technological Pedagogical Content Knowledge (TPCK). This entails an extension to educators pedagogy as it "requires an understanding of the representation of concepts using technologies" (Mishra & Koehler, 2006, p. 1029). One such application of educational technology is creating and using visualisations that can make, for example, the forces, state changes and trends of otherwise invisible phenomena visible (Gibbons, 2008), something so often lacking in students' awareness of electronic circuits.

Developing an understanding of pedagogy (both educational theory and practice) is critical for educators, just as critical as foundations of sound theory and practice are for engineers. Pedagogy gives us the power to critically evaluate student's understandings and our own teaching practice. We can then design ways in which our students can best gain deep understanding.

From theory to practice

Replanning the section on microcontrollers involved application of the theory discussed above: the three questions for students, formative feedback, epistemic ascent, scaffolding, direct instruction, student dispositions and educational technology. The educational technology used is an online assignment tool (Figure 1) employing visualisation of circuits and microcontrollers developed by the first author as part of his PhD research[1].

Qu 1: Where am I going? Development of a literacy goal

The previous course aim ('using commercially available hardware and developing a solution using a high level programming language') was replaced by a literacy goal. This goal was based on research from teaching and learning computer programming and relates to the student developing a mental model for a 'notional machine' (Sorva, 2013). The literacy goal became 'develop a viable mental model (useful abstraction) of a microcontroller based embedded system".

Qu 1: Where am I going? Development of abstract learning outcomes

Learning outcomes previously written for this course directly related to content such as GCC memory allocation and the AVR stack frame. These outcomes do not focus students on the goal of tertiary education which is 'academic' learning – the ability to work in the abstract. New abstract learning outcomes were written after reviewing academic literature in embedded systems relating to the understandings that new learners need to develop (Koopman et al., 2005; Winzker & Schwandt, 2011). Some of these are:
LO1: understand the interrelatedness of hardware and software in Embedded Systems (ES)
LO2: understand the ES as an automaton
LO3: understand the ES as reactive and responsive to its environment

Programming syntax and semantics for microcontroller programs is complex and students had previously completed the course with highly fragmented understandings (no epistemic ascent) of what a program for embedded systems was, as they had only ever had one laboratory experience. Their understandings were evident in their haphazard approach to software in the subsequent design course. Outcomes written for developing student software were:
LO4: understand the importance of transparent software practices for ES's
LO5: understand the benefits of using a state machine model for programming ES's

Qu 2: How am I going? Development of concrete success criteria

Understanding as an abstract learning outcome was unpacked into concrete success criteria; e.g. understand the ES as reactive and responsive to its environment was unpacked into:

- explain polling in relation to making an ES responsive
- explain contact bounce issues with physical switches and software de-bounce code
- describe how microcontroller timers are used to make an ES responsive
- explain how microcontroller external interrupts are used to make an ES reactive
- setup a microcontroller timer to make a microcontroller responsive to its environment

[1] (The course resources and online assignment are available at www.XplainItToMe.com. A simple online registration process with the University of Auckland is required to gain a logon ID).

- describe the significant characteristics and features of an internal ADC
- discuss issues of an ES's responsiveness with regard to polling, blocking and interrupts.

Success criteria begin with action verbs, this follows one practice surrounding success criteria which relates to student metacognition and owning their learning, where a student puts the words “I can” in front of each statement. Some of the success criteria are extended with the learning outcome, to purposefully direct students back toward the required abstract understanding, e.g. ‘explain polling in relation to making an ES responsive’.

Direct instruction and epistemic ascent

Lectures followed a process which began by focussing students on abstract learning outcomes and not the content to be covered. Demonstrations (conceptual models) used in lectures were not just ‘hooks’ to engage students but presented as rich contexts to describe the abstract principles in action. For example a quiz game controller was built and used to explain the previously introduced concept of the reactive nature of embedded systems and how polling made the ES reactive. It was also used in an assignment question to engage students with visualisation of polling as a software process (Figure 1). Lecture notes and the assignment were planned to build the hierarchy or epistemic ascent required for conceptually linked rather than isolated understanding. To learn about how an embedded system is made to be responsive to the environment involved building up a sequence of understandings. In the assignment a sequence of eight questions for hardware timers (Figure 2 and 4 are the first and last circuit exercises) and nine questions on ADC circuits, each designed as a sequence of proximal conceptual chunks which became increasingly more dense and abstract.

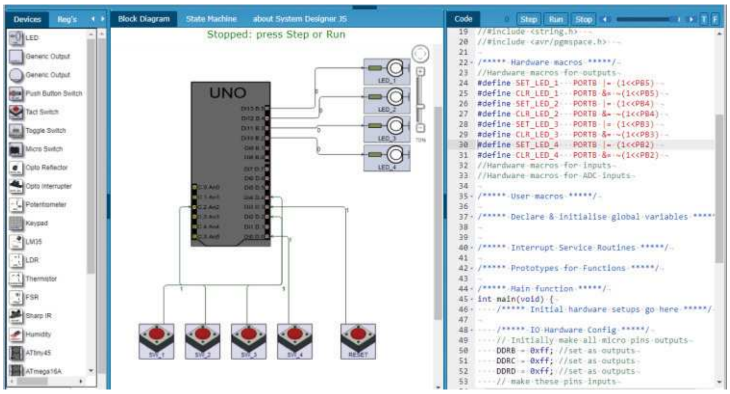

Figure 1: Quiz game - polling visualisation

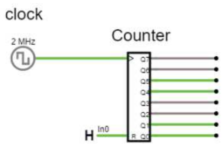

Figure 2: Simple counter circuit exercise

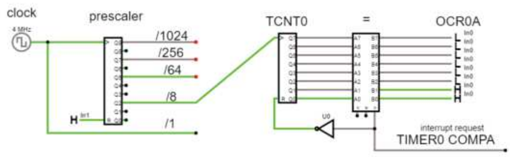

Figure 3: Full AVR timer circuit exercise

Scaffolding using educational technology

Novice students' learning to program in a proficient and transparent (easily readable and maintainable) manner is a crucial practice in embedded systems work. While commercial tools exist to help developers they require initial proficiencies that novices do not have. The assignment tool includes a microcontroller simulator (Figure 1) with a drag and drop interface for a variety of sensors that automatically creates well-structured program code allowing students to quickly grasp good practice. Once students are familiar with syntax and fundamental programming statements they often transition to completing given programs or predefined tasks, however they then struggle to transition to the next stage of designing programs. This course leads into a project-based design course where student's struggles with software were profoundly evident. This led to software design being introduced in the microcontroller theory course using the simulator's integrated state machine editor. State machines are devoid of syntax so are intuitive ways for students to begin software design. To scaffold students from the lower cognitive activities at the bottom of the Bloom's Taxonomy into the higher creative layers, where they can design their own software, the state drawing tool automatically creates program code as states and transitions are drawn.

This visible design process was used in the assignment to support students in identifying design issues relating to non-deterministic behaviour in state models.

Qu 2: How am I going? - Formative feedback using educational technology

The assignment tool provides immediate and specific feedback to students in the form of written comments and control of simulations. When an answer is correct feed forward comments become visible to reinforce abstract understandings along with next steps for learning. Some assignment questions were summative with marks only becoming visible after the assignment closed. To increase their learning power, feedback on these was provided after the assignment closed in order to give them a formative purpose as well.

One question that relied on providing a cue as feedback related to correct use of variable types in C, a crucial understanding for embedded systems engineers. Types were introduced in a lecture and case studies were presented where type errors had caused loss of life or major cost. Type usage was then practiced in the assignment via questions on type choice, overflow and underflow. The assignment question developed to investigate students' genuine understanding of type usage involved displaying numbers and had no reference to being about data types. Students were required to change the simulation from displaying numbers in the range 0 to 999 to 0 to 99999. The cue (subtle hint) was that the provided program could actually only display numbers in the range from 0 to 255 (not 999). An aware student would realise that the provided program would not work and then extrapolate as to what data type would be correct for their final program. In this question the simulator provided a safe environment for failure (as a well-planned laboratory experience could); following the adage that "good decisions come from experience and experience comes from bad decisions".

Qu 3: Where to next? – Student metacognition and learning dispositions

A number of strategies were employed to encourage students to develop positive dispositions towards their learning: overt use of learning outcomes in the lecture notes and assignment questions, the simulation based assignment with immediate feedback centred on learning outcomes, regularly encouraging students to begin the assignment and analytics integrated into the assignment front page showing students their own progress in comparison to that of the whole course.

Methodology and Results

A mixed methods approach was developed to collect and analyse data from the theory course and subsequent project-based design course in both 2015 and 2017. Prolonged engagement with staff and students in lectures, tutorials and laboratories allowed rich qualitative data to be collected from observations and discussions. Student voice was collected as much as possible as it is a recognised tool for assessing teaching practice (Cook-Sather, 2006) and follows the course goal of improving the student learning experience. Qualitative data from all courses were analysed thematically to identify both semantic and latent levels (Braun & Clarke, 2006). Quantitative data collected included test, assignment and examination results. Collecting data from several sources allowed a triangulation process to establish trustworthiness of the full dataset (Case & Light, 2011).

Examination results.

There was a marked change in student exam behaviour and grades from previous years. In 2016 86% of students had answered all four questions about the digital section of the course before choosing one of the two microcontroller questions; in 2017 student behaviour reversed with 86% choosing to answer both microcontroller questions and three of the digital questions. Scores also changed with averages for the two microcontroller questions moving from 59% in 2016 to 69% in 2017. Not all students succeeded in the course, 24 students did not do the assignment (their average exam grade was 51%) and several students began the assignment late and did not finish it.

Student voice.

199 of the 221 students attended the theory course laboratory in 2017; each student was canvased for their opinions about the course material. 174 students rated the material as understandable (25 added it was 'fun' or 'loving it'), 25 students rated it as difficult. Most students made comments indicating they developed good understanding and had a positive learning experience. Comments covered all aspects of the course: learning outcomes*, "it's not like other courses you know what is expected of you";* epistemic ascent, "*completely new, kind of easy to understand", "being taught C coding for micro-controllers without just making the assumption we know how to do this"*; visualisation, "*I can see C in action"*; the new assignment tool: "*yeah, I can do assignment questions on the bus", "simulations make it well worth doing the questions online", "I definitely think it was one of the best learning tools of any course"*; motivation, *"easier to do work when I am interested in it"*, course notes: "notes *make lectures interesting keeps me awake";* semantic density, *"it let us practically understand the things we were learning which I think was very important because the content is something that I personally found difficult to get my head around due to all the technical terms"*; direct instruction, "*Being shown the thought process our lecturers use when they solve problems*"; demonstrations, "*gadgets and devices were super helpful to see what was actually going on at the physical level*"; experience of learning, "*rather than theory which we are used to it's interesting";* formative feedback, *"feedback in questions is excellent";* metacognition*, "assignment was actually pretty good at helping me evaluate my learning";* link to rich context, *"real world examples which seemed kind of silly but ended up being really useful'*; student agency*, "I wouldn't have thought about it while playing a Gameboy but I got an insight and now can see the opportunities".* Some negative feedback about the course related to laboratories," *I would be keen to do some of the tasks with a real microcontroller instead of simulation*". Students also made negative comments which indicated their summative assessment driven approach to learning, e.g. "*there should be a fully completed version of the write-on course notes for exam preparation"* and *"it's difficult to tell how this will relate to questions in the exam"*. Some students also struggled with C and their feedback related to needing more fundamental programming skill development.

Course evaluations.

There was a marked increase in student satisfaction ratings with the course rising from a previously very unsatisfactorily ranking to above the university average.

Discussion

The course goals were to help students build a viable mental model (conceptual understanding) of an embedded system and improve their experience of learning; these were met for a clear majority of students. The results cannot be attributed to a single aspect of the change as there were significant changes to the course materials and staff. Many of the comments students left about the course however made direct or indirect reference to making learning visible and epistemic ascent. The visible learning process was centred on clearly articulating abstract principles in learning outcomes and regularly focussing the takeaway learning from concrete activities and success criteria back onto those abstract principles. The epistemic ascent was focussed around richly contextualised examples each developed through systematically linking epistemic (hierarchical) and manageable learning chunks suitable for novice learners and not treating content as isolated fragments.

A number of other comments made by students pointed toward other aspects of the course that also had powerful effects. These revolved around the clarity of the course materials and the clarity of presentation in lectures. These are already well-known indicators of student satisfaction in the department. The course also relied heavily on the use of a new online assignment tool to guide conceptual understanding via visualisations and promote student engagement through automated formative feedback. While visualisation is not a replacement for 'real' work with microcontrollers, several students directly commented on how it significantly enhanced their understandings of the dynamic processes involved.

The results overall indicate the benefit of a systematic coupling between educational theory and pedagogical practices when setting out to investigate and enhance student understanding. Future work in the course will involve a focus on metacognition; one of these aspects will be to structure the assignment grading in such a way as to reinforce regular activity rather than the common just-in-time approach currently used by many students.

Terminology

- Academic /Abstract knowledge – descriptions of descriptions of the world
- Agency – students conscious choices concerning their learning behaviours
- Assessment – gaining a valid realisation of student understandings
- Bloom's Taxonomy – six level cognitive hierarchy for planning learning outcomes
- Conceptual understanding – links between aspects of knowledge
- Epistemic ascent – the development of a linked learning hierarchy
- Expert educator – constantly refines practice through critique of their impact on learning
- Feedback – helping students identify where they have not understood
- Learning outcome – what we want students to focus their learning towards
- Literacy – being able to use knowledge in the real world
- Metacognition – self-awareness and control over ones thought and learning processes
- PCK –pedagogy and subject knowledge brought together to build student comprehension
- Pedagogy – discipline relating to teaching practice underpinned by educational theory
- Scaffolding – sequencing learning chunks that stretch but do not exceed student understanding
- Success criteria – concrete or contextualised activities that backup learning outcomes
- SOLO taxonomy, five level tool for recognizing students relational conceptual capabilities
- TPCK – representation of concepts using educational technology

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Does 'Just in Time' Design Thinking Enhance Student Interest and Appreciation of Customer Needs in the Design of Machine Elements?

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SESSION C5: Systems perspectives on engineering education

CONTEXT Design thinking which is becoming important in business and related disciplines has also begun to be engaged in engineering. This paper investigates the relevance and impact of student awareness of design thinking and customer needs prior to the onset of the gearbox design project assignment which is part of the course "design of machine elements" of the mechanical engineering program. This was implemented by providing students with 'Just-in-Time Teaching (JiTT)' of design thinking and stakeholder mindfulness into the course. The effectiveness of this intervention was assessed by conducting two surveys, one before and one after the presentation, and from focussed group discussions.

PURPOSE The research question is "Does 'just in time' design thinking enhance student interest and appreciation of customer needs in the design of the machine elements"?

APPROACH Sixty five second-year mechanical engineering students attended a presentation on design thinking with emphasis on sustainability and stakeholder needs prior to the design of machine elements (a gearbox) workshop. The students were also invited to participate in an interactive focus group discussion on design thinking one week after the presentation. Two surveys based on scores (1-5), one prior to the presentation of design thinking, and one, 6 weeks later at the end of the design assignment, were conducted to evaluate the impact of this presentation on students especially in their concept of gear design, cost, efficiency, aesthetics, safety, functionality, maintainability and sustainability.

RESULTS Compared to the first survey which was completed by 49 students, the results of the second survey which was completed by 38 students showed an overall improvement of the students' consideration of completion timelines, cost, efficiency, aesthetics, safety, maintainability and sustainability in their gear design. The most significant improvement was that their overall confidence level in the design of gears had improved by 27.2%.

CONCLUSIONS Dym et al. mentioned in their paper *Engineering Design Thinking, Teaching and Learning* in the Journal of Engineering Education (2005) that, "Design is what engineers do, and the intelligent and thoughtful design of the engineering curriculum should be the community's first allegiance". It is agreed that all engineering students need to have some element of design thinking in their curriculum. However a 'just in time' intensive mode of teaching may suffice and give the necessary outcomes.

KEYWORDS Design thinking, machine elements, mechanical design, just in time.

Introduction

According to Glegg (1969) in his book *The Design of Design*, science is about discovery and a scientist could discover a star but he will not be able to make one; an engineer could do it for him. Blumrich (1970) informed in his publication entitled "Design" in *Science*, that engineering, as a profession, is a creative process which involves the use of available knowledge, materials and other resources to solve new and existing problems. Engineering curricula have always been based on basic science with technological problems solved by applying scientific principles, and design has been said to be the core features of engineering (Simon, 1996). From the industry perspective, the design of effective solutions to meet social needs is deemed necessary in engineering programs and an attribute of an engineering graduate (Evans, McNeill, & Beakley, 1990; Sheppard, 2003). Engineering programs have also been said to lack sufficient scientific foundation (Braha & Maimon, 1997). These perceptions have led the industry to think that engineering graduates have difficulties practicing in industry. The perceptions have therefore led to industry's recognition to support academia in good design education (Todd & Magleby, 2004).

Design and engineering have many definitions. Sheppard (2003) has put into perspective what an engineer would normally do in his work and that is "scope, generate, evaluate, and realize ideas". In a way it is not dissimilar from the design process which to quote Sheppard is "scoping and generation, assessment, and selection (or evaluation) and the making or bringing to life (i.e., realization) of ideas". Dym, Agogino, Eris, et al. (2005) cited that the highest priority in future resource allocation decisions for engineering in academia should be the inclusion of design pedagogy.

The nineties and beyond saw the design of products and services became a huge component in the business world and corporations were investing in becoming design leaders (Dunne & Martin, 2006). Design thinking which was becoming important in business was also featuring in engineering and architecture.

So what is design thinking? Design thinking is how designers think and learn. It is difficult to teach and, reflects the process of inquiry and learning in a systems context with the individual making decisions as they proceed, in a team based collaborative fashion (Dym et al., 2005). It also depicts the involvement of a client or customer and decisions are made through an ongoing feedback mechanism between "contractor/ engineer/ designer and client" realising in an optimum product or process. It is cross disciplinary and embraces creative thinking in offering solutions to problems. According to Parmar (2014), design thinking plays a critical role in educating a new class of engineers, and that design thinking can be integrated as a core subject in the first year via project based engineering and promotes new product development. Açar and Rother (2011) introduced the design thinking approach as a new means of systematic innovation, integrated the approach in engineering education, and reflected a complex process of inquiry and learning that merges engineering with design.

The initial intent in this study was to introduce design thinking as a course in the mechanical engineering program and to encourage students to be mindful of their stakeholders, the ecosystem and to use science, technology and design to solve problems (Chang, 2013). Several engineering programs worldwide have embedded design thinking into specific programs or as topics in specific courses/subjects. The question is whether these methods have delivered the expected outcomes?

Anecdotal feedback from colleagues in other universities and Griffith University informed that a standalone course in design thinking is time consuming, may not achieve the intended benefits as students tend not to integrate it into their core courses and their learning and decision making. Students have a very short attention span and tend to compartmentalise their thoughts. It is therefore decided that, in this study, to introduce mindful design thinking 'just in time' into the design of machine elements course. 'Just-in-Time Teaching' or JiTT (Novak, Patterson, Gavrin, et al., 1999) has a similar resemblance to the 'Just-in-Time' manufacturing process pioneered by Toyota in the 1970s (Monden, 1998) whereby students/ participants are introduced to a topic/process or a learning assignment just in time for its application. The main element of JiTT is active learning. Students control the learning process and this engagement between student and teacher which can be held anywhere is further enhanced with the use of electronic technologies (Marrs and Novak, 2004). Students who have difficulties in understanding a topic, could attend a pre class session to address these difficulties. JiTT allows the instructor the possibility to respond to the students difficulties when the students come to class and the students determine the discussions and lead the discussions (Mazur and Watkins, 2010; Marrs and Novak, 2004; Thomas, 2011). The student input is therefore ‘just in time’. JiTT used in the teaching of science and science majors in undergraduate and postgraduate programs has shown improved student attitudes and study habits leading to interactivity and also increased retention (Marrs and Novak, 2004). It was reported that using a concept-based JiTT curriculum may encourage students to study and discuss the classroom material at deeper level (Riskowski, 2015).

Included in the following sections is an approach to providing students with JiTT mindful design thinking, the results of two student feedback surveys - one of which conducted before and the other after the presentation, the feedback from focussed group discussions, and, finally the conclusions of this study.

The Approach

In this investigation it is decided against the implementation of a full course in design or, any structured curriculum in design thinking as the curriculum was already very packed. The strategy was, to quote Knight and Wood (2005), to “teach more by lecturing less” and to use a version of JiTT to incorporate design thinking and mindfulness into the design of machine elements course. The approach was to provide the students with an interactive presentation on design thinking and mindfulness, or as it was introduced to the students ‘mindful design thinking’ at week four. Week four was just before the students start their design project.

The design of machine elements is a second year course in the mechanical engineering program at Griffith University. It is a course on modelling and design of power and motion transmission and control machine elements such as shafts, bearings, gears, fasteners and joints, etc., using physics, mathematics and core mechanical engineering principles (statics, dynamics, stress analysis, failure prevention, etc.). This course is delivered through a combination of specially developed lectures, design problem solving tutorials, and hands-on design projects in the design workshop. The main learning outcome is the students” acquisition of strong analytical knowledge of machine elements, their design and load carriage / or power transmission mechanics. The project activities are arranged in a way to be able to motivate each student by providing experiential, authentic, and challenging learning experiences. As many second year students have not as yet had any experience with a power transmission machine, the design of the gear box exploration and design workshop which are key hands on activities is organised into two main phases and scheduled to start from the second week of the semester. In phase one, students explore and examine a real world 3-speed gearbox used in a manual transmission car as the first project. Students form project teams with around 5-6 members. The lecture on the general theory of gears which was normally scheduled during week four. To help the students prepared for the workshop activities, a briefing on the basics of gear trains is deliberately brought forward to week one.

In phase two, students design a gearbox based on a set of assigned conditions using the knowledge they have acquired. This is organised with a specific application background, such as for a conveyor system or an industrial saw. The design team need to determine the configuration and key parameters to satisfy the project task specifications, required strength and functionality, and to create a set of engineering drawings for the gearbox. In week four, along with the briefing of the design tasks, an introduction of the design thinking and mindfulness concept is included as an integral part for students to adopt in their design practice.

From past observations, student groups are typically keen to jump into designing the gear box and to finish the project. There is lack of discussion or preparation and also the discussion on the needs of the stakeholder (customer) are not a priority. The knowledge of design thinking which systemises the team discussion process and creates mindfulness of customer needs such as costs and sustainability would be useful.

The presentation on design thinking to 65 students of the Design of Machine Elements course was short and interactive and workshop style. It covered some basic concepts and applications of design thinking and mindfulness, and a few case studies including IKEA’s success in the furniture industry. It was held at 9 am at the beginning of the class when the students are presumably “fresh and receptive”. This presentation/workshop was literally ‘just in time’ and around 15-20 minutes. Students were then encouraged to engage in inter and intra group discussions for around 10 minutes. The teams then proceeded with their design project over the next 6 weeks with a weekly verbal reminder to use design thinking in their product design. The students were invited to participate in an interactive focus group. This discussion was conducted whilst the students were undertaking their project work within their project groups. The topic discussed was the usefulness of the JiTT presentation.

Results

Table 1. Survey questionnaire

No.	Questions
1	I am confident in carrying out stress analysis.
2	I am confident in completing engineering drawings for a typical machine element.
3	I am confident in the design of a shaft for motion and power transmission.
4	I am confident in the design of gears.
5	I am confident in the design of a full set of simple gearbox.
6	In my design, I always consider the functionality of the machines or devices.
7	In my design, I always consider the safety of the machines or devices.
8	In my design, I always consider the machinability, assemblability, and maintainability of the machines or devices.
9	In my design, I always consider the cost of the machines or devices.
10	In my design, I always consider the sustainability of the machines or devices.
11	In my design, I always consider the ecosystem related to the machines or devices.
12	In my design, I always consider the aesthetics of the machines or devices.
13	In my design, I always consider the efficiency of the machines or devices.
14	The teaching (lecturers, tutors, etc.) on this course is effective in helping me to learn.
15	What did you enjoy most about this assignment?
16	What did you enjoy least about this assignment?
17	Please provide feedback and suggestions on the arrangement of the design workshops and the course.

Two surveys were conducted in the week four and week ten respectively in the Design of Machine Elements class. The questionnaire consisted of 14 quantitative questions (No. 1-14), for which students were asked to indicate their response on a scale of 1-5, where 1=not at all; 2=very little; 3=some; 4=quite a bit; 5= very much; and also 3 qualitative questions (No.

15-17) with open-ended responses expected. The questionnaire is listed in Table 1. The results of the two surveys conducted are summarised in Table 2 for the 14 quantitative questions.

Table 2. The results of the two surveys conducted (for quantitative questions)

No.	Questions	Survey 1	Survey 2	Improvement
1	I am confident in carrying out stress analysis.	3.55	3.63	2.3%
2	I am confident in completing engineering drawings for a typical machine element.	3.47	3.39	-2.2%
3	I am confident in the design of a shaft for motion and power transmission.	3.16	3.54	11.9%
4	I am confident in the design of gears.	3.02	3.84	27.2%
5	I am confident in the design of a full set of simple gearbox.	2.84	3.42	20.6%
6	In my design, I always consider the functionality of the machines or devices.	3.96	3.84	-3.0%
7	In my design, I always consider the safety of the machines or devices.	4.00	3.95	-1.3%
8	In my design, I always consider the machinability, assemblability, and maintainability of the machines or devices.	3.67	3.87	5.3%
9	In my design, I always consider the cost of the machines or devices.	3.65	3.79	3.7%
10	In my design, I always consider the sustainability of the machines or devices.	3.67	3.84	4.6%
11	In my design, I always consider the ecosystem related to the machines or devices.	3.53	3.61	2.1%
12	In my design, I always consider the aesthetics of the machines or devices.	3.59	3.66	1.8%
13	In my design, I always consider the efficiency of the machines or devices.	3.69	3.96	7.2%
14	The teaching (lecturers, tutors, etc.) on this course is effective in helping me to learn.	3.57	3.71	3.9%

The first survey which was completed by 49 students, the results of the second survey which was completed by 38 students showed an overall improvement of the students' consideration of completion timelines, cost, efficiency, aesthetics, safety, maintainability and sustainability in their gear design. The most significant improvement was that their overall confidence level in the design of gears had improved by 27.2%, while the confidence level in the design of a full set of simple gearbox had improved by 20.6%.

As for the focussed group discussions, all 15 project groups of between 4-6 students agreed that "design thinking was useful". Three groups informed that discussions with stakeholders on their needs were extremely important and should be included in the project; however one group was concerned that this would impinge into the project time. Five groups suggested that design thinking be offered as a course in the engineering program. All groups agreed that in the scheme of things students may not use design thinking effectively as they are always short of time and therefore they were not so sure of the usefulness of including a standalone design thinking course into the program. Two groups suggested that design thinking be used in Industry Affiliates Project (IAP). IAP is the workplace internship undertaken by students. Overall all groups agreed that the JiTT design thinking presentation was useful and interesting.

Conclusions

Dym et al. mentioned in their paper *Engineering Design Thinking, Teaching and Learning* in the Journal of Engineering Education (2005) that, "Design is what engineers do, and the intelligent and thoughtful design of the engineering curriculum should be the community's first allegiance". To quote the students interviewed in this project, there is a need to have some element of design thinking in their curriculum as well as the notion of mindfulness of the stakeholders needs. This study has given us indications that a JiTT presentation has improved students' perception of aspects which would be of interest to stakeholders/clients/customers such as completion timelines, cost, efficiency, aesthetics, safety, maintainability and sustainability in their gear design. There would be a need to investigate further to ascertain whether there should be a standalone course in design thinking with mindfulness or whether it should be JiTT presentations. The suggestion of the incorporation of design thinking into Industry Affiliates projects is one that could be considered and could be a test bed to ascertain improvements in students' design of machine elements as well as cost benefits and customer satisfaction.

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A scientific framework for testing creativity enhancing techniques

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SESSION: S2: Educating the Edisons of the 21st Century

CONTEXT Among the hot topics of Engineering Design research, creativity enhancing techniques play a key role with abundancy of approaches, methods and tools proposed by different authors to address a range of objectives such as exploring new product opportunities, suitable framing of ill-defined problems, overcoming mental inertia and design fixation phenomena, improving co-creative activities etc. Typically, those research activities claim some advantages with respect to the existing literature through case studies or sometimes through controlled experiments. However, the impact of the application context, the attitude and background of participants, but even the variability of the design task of the experiment have a dramatic impact on the performance of the subjects. Consequently, it is very hard identifying regularities and common aspects to draw some general conclusions and make a step ahead towards the definition of comprehensive models and related educational approaches. A further limitation is that variability of testing conditions and observation means make it difficult to replicate those experiments to scale-up the investigation with more significant data sets.

PURPOSE This study aims at proposing a reference set-up for design experiments, suitable to test creativity-enhancing techniques under controlled conditions.

APPROACH The proposed testing framework can involve either students or practitioners, working in teams or as individuals, divided in different groups of treatment, one of which receives no treatment and plays the role of control group. Each group should count a sufficient number of individuals or teams receiving the same treatment to allow for analysis of statistical significance of the results. The experiment consists of two rounds: the first does not involve the application of any treatment to check whether the testing groups show homogeneous performance in terms of idea generation capabilities. In the second round, all groups but the control one, receive some specific instruction or set of stimuli, suitably differentiated, to observe the impact of the creativity-enhancing techniques under study. A panel of experts assesses groups' performance by means of the evaluation of all the generated ideas, according to four reference metrics.

RESULTS The proposed experimental set-up proved to be applicable in several contexts, to compare the impact of different creativity enhancing techniques. So far, it allowed to compare the effects of: *(i)* creative stimuli based on analogical thinking; *(ii)* information extracted from patents as a trigger for idea generation; *(iii)* the introduction of external knowledge from biology represented with different functional/causal modelling techniques.

CONCLUSIONS The paper proposes a structured experimental approach to test creativity-enhancing techniques in terms of impact on design performance and usability, as well as to monitor the learning process of target groups. The tests carried out so far have mostly explored the applicability of the experimental set up varying different creative techniques and operational environments; the structured definition of the experiment enables the replication of a test by different researchers with controlled changes on the experimental conditions.

KEYWORDS Design creativity, creativity stimuli, creativity metrics.

Introduction

Design creativity has become a hot topic in Engineering Design for at least a decade, and significant advancements have been done in understanding how to activate creative thinking while performing design tasks. Creative stimuli leverage several mechanisms such as the identification of analogies (e.g., Christensen & Schunn 2007; Goel 1997) or the guided exploration of resources available in the system or easily accessible (e.g. Becattini et al, 2012). Even though some experiments show that also “internal” stimuli, i.e. retrieved from the company's information repository, can bring advantages to idea generation in brainstorming sessions (e.g., Howard et al., 2011), more extensive studies are dedicated to the injection of relevant pieces of information from other fields of application (e.g. through patents, as in Fu et al, 2015), or from other domains (e.g. Bar-Cohen, 2006; Bonser & Vincent, 2007). The research in this domain investigates several further aspects, such as the degree of interactions in brainstorming activities (Faure, 2004) or the means used to propose creative stimuli, e.g. in textual, graphical or mixed form (Gonçalves et al., 2016).

Overall, this multitude of studies has increased the knowledge on influential factors, but several fundamental limitations remain:

- in many cases, the conclusions of proposed experiments are not robust enough, due to the difficulty of involving large samples of subjects, especially when these are practitioners from industry;
- nor it is possible to scale-up complementary studies by comparing their results, since many uncontrolled variables change in the set-up of the experiments (e.g., the application context, the attitude and background of participants, the design task of the experiment), thus affecting the interpretation of the observed phenomena.

Not surprisingly, contradictory outcomes emerge from apparently similar studies, and this makes it very difficult the identification of regularities and common aspects to draw some general conclusions and make a step ahead towards the definition of comprehensive models. In turn, this limits the efficient advancement of the research in the field.

This study proposes a reference set-up for design experiments, suitable to test creativity-enhancing techniques under controlled conditions. The proposed testing framework exploits the experience of previous experimental activities carried out by the authors and by other scholars in the engineering design domain. As such, more researchers might organize their studies according to the same framework, thus allowing regular and structured replications of experiments, as for instance in the pioneer experience proposed by Belski et al. (2016).

The paper is structured as follows: the second section describes the proposed framework and its rationale; then, two exemplary applications of the same are proposed, to show the adaptability of the framework to different contexts and specific objectives. Eventually, the last section proposes the conclusions of the authors based on the evidences emerged so far.

The testing framework

The testing framework has to be adaptable to a large variety of experimental conditions, so as to allow the observation of the influence of diverse controllable factors, such as:

- the profile of the subjects (e.g., distinguished by age, gender, education and background, cultural environment, etc.);
- the design task (e.g., constrained problem solving task, exploration of the design space through divergent thinking, etc.);
- the designing conditions (e.g., duration of the design activity, work in teams or as individuals, the features of the test location etc.);
- the creative stimuli differentiated in terms of source of information, expected mechanism of creativity enhancement, representation form of the stimuli, etc.

At least two different groups of treatment should be set up, one of which receives no treatment and plays the role of control group. In the authors' experience, typically four groups are organized, i.e. a control group and three different groups of treatment, so as to allow a broader exploration of the impact of influential factors on idea generation.

Each group should count a sufficient number of individuals or teams receiving the same treatment to allow for analysis of statistical significance of the results. The basic elements that constitute a modular unit of the experimental set-up are the followings: several individuals or teams (subjects) belonging to a certain group receive the same treatment; the controlled input is a design task to be approached by the subjects; the observed output is the collection of all the ideas generated by the subjects; other influential factors, such as the designing conditions and the creative stimuli, are controlled so as to ensure the same treatment to the entire group.

The experiment consists of two rounds (figure 1): the first one does not involve any induced method or techniques, nor it introduces any external stimulus to the subjects. The rationale of this round is to check whether the testing groups show homogeneous performance in terms of idea generation capabilities. Therefore, the outputs produced by the groups in this phase are compared through the ideation metrics described below and the randomization of the subjects is considered adequate if no significant statistical differences emerge.

In the second round, instead, all groups but the control one (Adair et al., 1990) receive some specific treatment, i.e. they are exposed to different instructions or set of stimuli, or they are invited to work in different controlled operating conditions. The treatment of the test groups should be suitably differentiated so that:

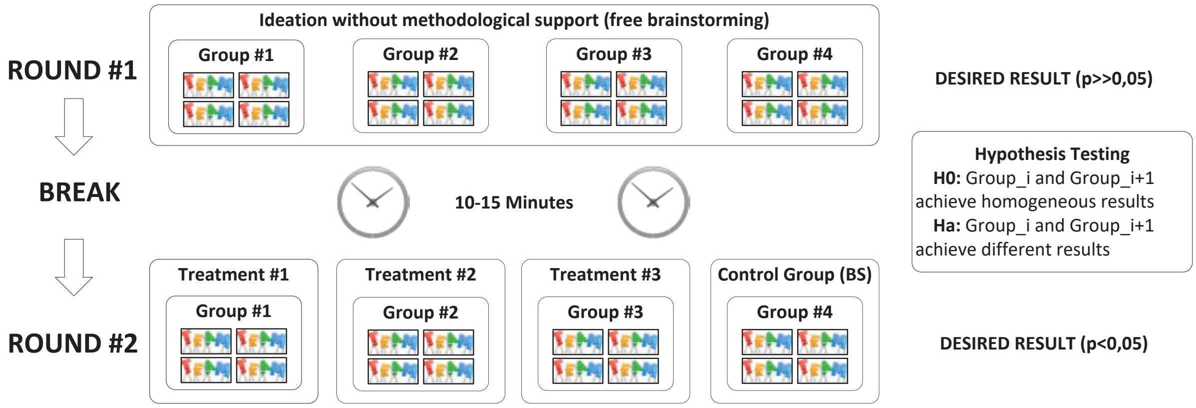

Figure 1: Organization of the two rounds of the experiment

- statistically significant differences can be observed between the output produced by the test groups;
- the controlled variations of the testing conditions are coherent with the objectives of the specific study.

All the generated ideas (of either rounds of the experiment) are evaluated by a panel of experts who assess groups' performance by means of four well-established metrics in the field literature (Shah et al., 2003):

- Fluency, as a measure of quantity of generated ideas;
- Novelty, as the difference between the generated idea and the initial state of the solution (ex-ante or a-priori), or in terms of originality with respect to the rest of the cohort of subjects (ex-post or a-posteriori);
- Variety, as a measure of the diversity among a set of generated ideas, representing the capability to explore the solution space;
- Quality, as a measure of the goodness/viability of a generated idea (if possible) or completeness of the idea description (under the assumption that more detailed descriptions are more likely to be based on supporting arguments).

More in detail, the assessment of ideas according to the above metrics performed by the panel of experts should be checked in terms of degree of agreement among the raters, e.g. by means of the Kendall's W coefficient of concordance. The results of the individuals/teams constituting each group are clustered to generate a descriptive statistic for the population administered with the same treatment. The resulting data are compared to evaluate:

- the uniformity among the different groups before any treatment (Round 1): this check on the goodness of the randomization for group composition is a necessary pre-condition for the meaningfulness of the second round of the experiment;
- the differences between the different behaviour of the subjects exposed to a different treatment (Round 2).

To evaluate the significance of different ideation performance between groups, Kruskal-Wallis is chosen against ANOVA because of the unknown nature of the distribution of the population, thus, of its variance. Then, differences due to the effect of different treatments are explored by means of one-to-one comparison between different groups. These differences are every time measured through meaningful statistical estimators to the effectiveness of ideation performance.

Exemplary applications of the testing framework

This section briefly describes two different experiments based on the proposed testing framework, so as to show its applicability in different situations and with different specific objectives, despite sharing the same overall goal to observe the impact of different creative stimuli on the ideation performance.

Testing creative stimuli for design-by-analogy

Design-by-analogy is a well-known practice in which analogy is applied in the design process for helping the designers to get inspired to solve a target problem (Christensen & Schunn, 2007; Goel, 1997). Near-field analogy appears when the target and the analogical source are from the same or very similar problem domain, while far-field analogy appears when they are from different problem domains. Despite the effect of analogies on design performance has been studied by many scholars and several literature sources share the results of carefully conducted experiments (e.g. Chan et al., 2011), contradictory conclusions emerged when comparing the outcomes of stimuli characterized by different analogical distances. It is therefore necessary to extend such studies to a wider set of tests to understand the impact of factors not yet controlled by the researchers. Among these, the authors intend to explore the impact of specific training on the capability of designers, either novices or experts: the recognition of analogies and the generation of idea through the transposition of some elements into the desired target is not necessarily intuitive and can be improved by practice.

With this purpose, a sample of novice mechanical designers, subdivided in small design teams, participated in an experimental activity structured as described in the previous section. The experiment was conducted at Hebei University of Technology in China, with 84 postgraduate students (17F-67M – MS in mechanical engineering). Randomly, 21 participants were assigned to the "Control Group". The same amount of subjects also composed the groups exposed to near-field analogies, middle-field analogies and far-field sources of analogy. Each group counted 7 design teams 3 members each to recreate a typical collaborative design session.

The first round of the test consisted of a 10-minute brainstorming activity with no stimuli. In the second round, two different stimuli were introduced every 10 minutes for a total amount of 40 minutes (8 stimuli per team).

The design task was the proposal of ideas for the next generation of vacuum cleaning robots. The introductory presentation discussed some of the most common problems of these device as a preliminary design brief: quality and efficiency of cleaning are low, especially for corners and edges of the room; the collection device is hard to clean; the robot easily gets stuck and the wheels are also easily twined by strings, cables, etc.; other problems, such as high noise, insufficient energy, etc. During the presentation of the case study, students were encouraged to generate also ideas beyond the scope of the proposed problems. The design stimuli, presented to the subjects as a combination of text and picture, were devices or products supposedly suitable as stimulus to address the problems of cleaning, moving, saving energy and decreasing noise.

The experiment took place in a large classroom to allow the communication within every team and prevent any between-team interference. During the experiment, surfing the internet was forbidden and participants had to write down their ideas as text and sketches on the ideation template handed out at the beginning of the experiment. The participants also had to specify the problem they focused on, the stimulus that inspired them and the team name.

The results of the Kruskall-Wallis test on the output of the first round of the experiment confirmed that there are no significant differences between the groups in terms of quantity of generated ideas ($p=0.904>0.05$), novelty of the generated ideas computed as the average score of novelty for each of the groups ($p=0.228>0.05$), average quality of ideas among groups ($p=0.692>0.05$) and related variety of what they ideated ($p=0.838>0.05$). In other terms, it can be stated that groups have been properly created through randomization and therefore the emerging differences between groups in the second phase, if any, depend on the effect of analogical stimuli the groups are exposed to.

The analysis of the ideas generated in the second round of the experiment through the Kruskal-Wallis test shows that differences among groups are significant for the average score of novelty ($p=0.004<0.01$), quality ($p=0.000<0.01$) and for the variety of ideas ($p=0.016<0.05$). This implies that the analogical stimuli in this test had a statistically evident influence on the design outcome. On the contrary, the results show that the differences among quantity of ideas among the groups did not (statistically) depend on the stimuli ($p=0.116>0.05$). The authors interpret the latter as due to the small amount of time assigned to the subjects for the generation of ideas after the introduction of each pair of stimuli.

Figure 2 shows a comparison of the performance metrics related to novelty, variety and quality achieved by the four groups of treatment.

Without focusing on details that are beyond the goal of the present paper, the following essential results emerge from this experiment:

- Average novelty index displays that the ideas inspired by near-field analogies are significantly more novel than the ones generated with different treatments, including the Control Group. In addition, compared to the control condition without any stimuli, both medium-field and far-field analogy are tending towards higher novelty design output, even if the effect is not fully statistically significant.
- Similarly, the quality of ideas inspired by near-field analogies is better than the ones inspired by the far-field analogy and control conditions. Unlike for the influence on novelty, the far-field analogy negatively affects the percentage of ideas having higher quality. This suggests that distant analogies may require designers to retrieve, map and transfer a hardly manageable amount of information for cognition and this appears as more difficult without a dedicated training.

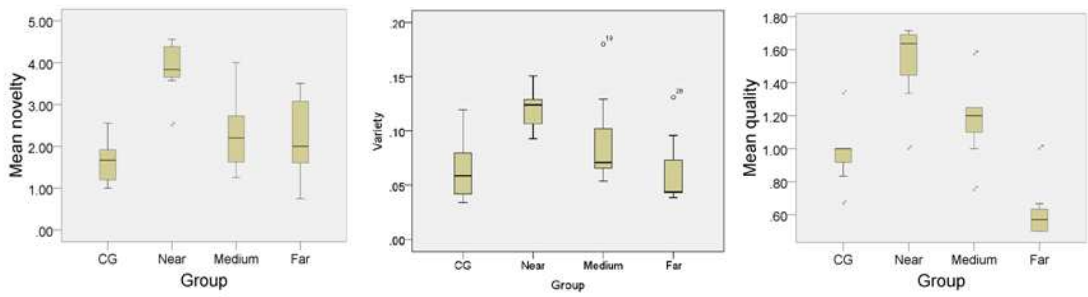

Figure 2: Comparison of different analogical distance stimuli (metrics from Shah et al., 2003)

- About variety, the results only allow inferencing that near-field analogies help designers generate ideas in a broader design space than what control condition, medium-field and far-field analogy do. This could also reinforce the former statement about the effectiveness of near-field analogy, as they can also inspire better ideas with higher novelty and quality.

In summary, this experiment shows that near-field analogies play the most beneficial role in the ideation at least when proposed to designers not specifically trained on this practice.

Testing information extracted from patents as creative stimuli

As a second exemplary application of the same experimental framework, the authors propose hereafter an experiment with significantly different conditions and specific objectives with respect to the study described in the previous section: practitioners instead of students as subjects; information extracted from patents as design stimuli; analysis of the impact of different representations on the ideation performance of designers.

The rationale of this study (Authors, 2017) is that among the creative stimuli proposed in literature, patents represent a suitable option for R&D engineers, since they are supposed to be acquainted with this kind of documents, and they are not expected to be as sceptic as for other documents of non-technical origin. Patents as stimuli, even if recalled from the same domain, can be meaningful for these target users since also incremental innovations might allow the exploitation of a fruitful business for the patenting subjects.

To study the effect of different patent content representations as creative stimuli in ideation processes, the investigation requires comparing the outcomes of alternative approaches using patents. Since analogies have witnessed to be effective for increasing the novelty and the quantity of ideas (Chan et al., 2011), and patents as sources of analogies demonstrated effectiveness in idea generation (Fu et al, 2015), their simplest representation (Patent Full-Text - PT) has been chosen as one of the stimuli for the comparison of treatments.

Two more representation forms have been added in the experiment:

- Problem-Solution Matrix (PS) Map (Suzuki, 2011);
- An original diagram (Figure 3, Parvin et al., 2017) based on the concept of TRIZ contradiction, since compared with alternatives such as fishbone and fault-tree diagrams, TRIZ contradictions focus on problems and solution using design parameters, corresponding respectively to design variables (what designers can change) and design requirements (Becattini & Cascini, 2013).

Overall, four different treatments were adopted for this experiment: Brainstorming (Control Group - BS Group); the Problem-Solution Matrix Map (PS group); the TRIZ Contradiction map (PS+TC group), and Patent Full-Text (PT group). The last three sets of stimuli were built out of the same patent corpus.

The experiment was conducted in Iran in collaboration with a training and consulting institute: fifty-six (56) R&D engineers (45 M; 11 F), with an average working experience of 9,2 years (Std. deviation 1.5) and different backgrounds (mechanical/industrial, chemical, electronics, computer science…), were involved and randomly subdivided into 4 groups, one per each of the abovementioned treatments. The 14 people in each group were randomly organized into 7 teams of 2 engineers each. This enables gathering a sufficient amount of experimental data for each treatment (7 data points) and have real-like design conditions for the team (2 people sharing and generating ideas on the design task).

The experiment was organized into two rounds – 30 minutes each consistent with the findings of Howard et al. (2010) on the saturation of generativity. During the first round, the 28 teams of R&D engineers were asked to generate inventive ideas they consider worth of patenting. The second round started after a 15 minute break and the 4 groups received a different treatment each.

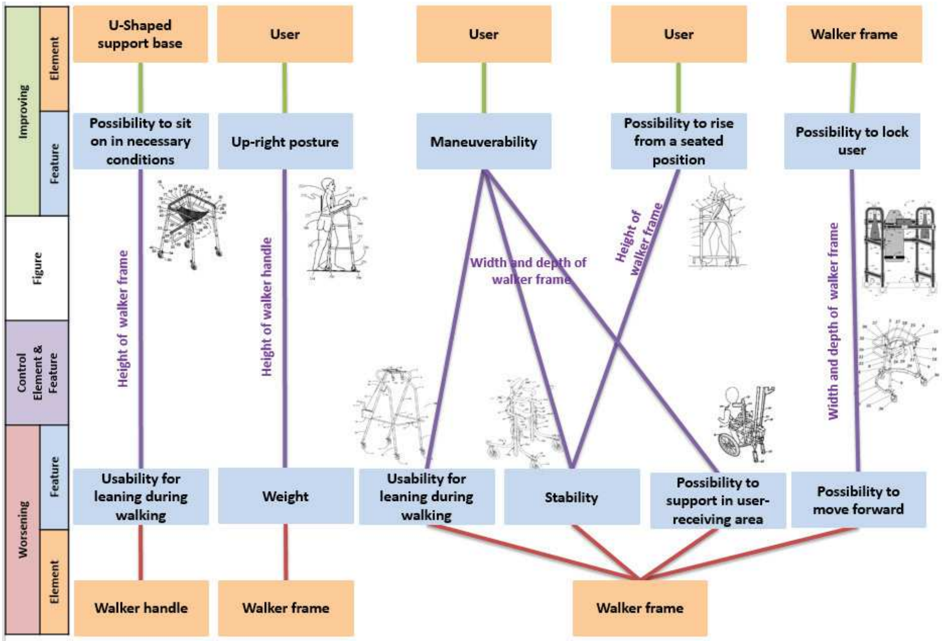

Figure 3: Exemplary TRIZ contradiction map used as patent information-based creative stimuli

To avoid biases due to misinterpretations, the design task regarded the generation of inventive ideas for a walker (or walking frame), a device for disabled or elderly people who need additional support to maintain balance or stability while walking. Its intrinsic simplicity released the subjects from having specific competencies to understand its current functions and related working principles. The data collected in the experiment were analysed with the same metrics described in the previous example and the same logic (for more details, see Parvin et al., 2017). Overall, the following conclusions were drawn:

- patent-based design tools trigger better performances than brainstorming;
- there is no statistically significant difference between the use of the patent map per se and with the contradiction map for none of the three metrics, despite the results suggest potential advantages regarding enhanced novelty;
- the combined use of the problem-solution and contradiction maps increases, with statistical significance, the quantity of ideas, compared to full-text patent stimuli and simple brainstorming;
- the combined use of the problem-solution patent map and contradiction map increases, with statistical significance, the novelty of ideas, compared to simple brainstorming;
- the use of the problem-solution patent map per se increases, with statistical significance, the variety of ideas, compared to full-text stimuli and simple brainstorming.

Conclusions

The paper proposes a structured experimental approach to test creativity-enhancing techniques in terms of both impact on design performance and usability, as well as to monitor the learning process of target group.

The proposed experimental set-up proved to be applicable in several contexts, to compare the impact of different creativity enhancing techniques. So far, it allowed to compare the effects of: creative stimuli (as examples taken from fields at different distance from the target application) on analogical thinking; information extracted from patents and represented in different forms as a trigger for idea generation; the introduction of external knowledge from biology represented with different functional/causal modelling techniques (not described in this paper due to space limitations).

Among the results, it is worth mentioning that sometimes the experiments brought some unexpected results with respect to other literature studies, which can be justified by reflecting on the specific cultural or educational context where the test was conducted. Those reflections might have significant implications in the definition of educational approaches.

Despite the tests carried out so far have mostly explored the applicability of the experimental set up varying different creative techniques and operational environments, the structured definition of the experiment enables the efficient replication of a test by different researchers with controlled changes on the experimental conditions. The authors believe that efforts in this direction will lead to a higher reusability of research achievements and, ultimately, to a more efficient growth of the scientific community working on design creativity.

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What is easier to solve: open or closed problems?

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SESSION

S2: Educating the Edisons of the 21st Century

CONTEXT

Technical innovation can be roughly subdivided into two categories. A first category is concerned with solving problems that are well understood, and those problems are often formulated as a contradiction: the engineer tries to improve a parameter of a system for a certain reason, but unfortunately another parameter of the system gets worse. The second category is concerned with problems that are not known, basically the engineer tries to integrate a new function.

PURPOSE

It is the purpose of this paper to compare how easy students find it to solve the respective problem categories, and how much enjoyment they have in dealing with these, as this may influence in which order to teach respective analysis and problem solving tools.

APPROACH

Cases for each problem category were distributed to student groups to work on using a structured problem solving technique. Directly after the exercise the individual students were given questionnaires to evaluate various aspects of the exercise. The result of questionnaires was then analysed and evaluated.

RESULTS

No statistically significant difference could be established in how easy students find it to solve problems of the two problem categories. Also, no statistically significant differences could be established in the enjoyment that students had in solving problems of the two problem categories.

CONCLUSIONS

If there is a difference in how easy students find it to solve the respective problem category, then it may be prudent for a teacher to start teaching problem solving techniques that relate to the problem category that is easier, or more enjoyable to work on. However, no such statistically relevant difference could be detected.

KEYWORDS

Open problems, closed problems, TRIZ, inventive principles.

Introduction

The application of creative techniques in business is of increasing importance for companies to gain and keep an advantage over competition, as stated by Dobrusskin, Belski and Belski (2014). A number of techniques is used for these purposes, and TRIZ, the Theory of Inventive Problem Solving has, in recent years, been one of the more interesting of these techniques for both engineers and designers (Aoussat, Cavallucci, Trela and Duflou, 2013). Analogous with the growth of importance of including creative techniques into the portfolio of processes of companies, there has been a growing interest of teaching these creative techniques in education in general (e.g., Thijs., Fisser and Hoeven, 2014), and specifically in the engineering education. Belski *et al.* for example has included TRIZ in the education of students at the RMIT Melbourne (e.g. Belski, Baglin, & Harlim, 2013; Belski & Belski, 2013).

Generally creative challenges can be split into one of two categories. Firstly, closed problems, which are characterized by the fact that a specific problem situation can be well described. Secondly, open problems, which usually involve a search for something new, but apart from a crude scoping the “newness” is not further defined. This fact is recognized, for example, in the TRIZ training material of Ikovenko *et al.* (2013), by having different tools clustered to either be more suitable to tackle one – or the other of these creative challenges.

If a substantial difference can be established in how students experience the problem solving process for each of these two categories of problems, this may enable a teacher to give a student a better learning experience, for example by starting to teach a problem solving technique using the easier, or more fun technique first.

The process of solving problems has a number of different aspects. Firstly, to solve non-trivial problems is not easy. Why else would one need creative techniques to solve these problems? Consequently a problem solver will find some challenge in solving the problem at hand.

The first hypothesis that was investigated in this study was therefore to evaluate the level to which a student was challenged while solving different types of problems. Based on numerous informal experiences it reads: (i) subjects do not experience any difference in the level of challenge when solving open problems compared to solving closed problems.

Secondly, as noted for example by K. Gadd (2011), the process of successfully solving difficult problems is generally enjoyable. Again, based on numerous informal experiences the second hypothesis that was evaluated reads: (ii) subjects have the same amount of enjoyment while solving open problems as they have solving closed problems.

Definition of open and closed problems and their resolution

Particularly for open problems a number of different definitions are circulating. In the context of this investigation a specific definition of both closed problems as well as of open problems was used.

Closed Problems

The most common definition of a closed problem is that there is one correct answer to it (mathematics). Translated into the engineering domain this would mean that the set of possible solutions will be reasonably clear for an expert in the problem's domain. In the framework of this investigation a closed problem refers to a problem situation in which the problem parameters can be well described. In the industrial practice such problems are typically encountered in development or in the field. Doors for example should be constructed to close well with the surrounding doorframe. However, it the door is constructed in such a way that a finger of a child is squashed between the door and the door frame at the side of the hinges, an occurrence that is normally to be avoided, the situation could be described as a closed problem. If such a closed problem poses some intellectual challenge for it to be solved, then the problems can be described in TRIZ terms as a contradiction (e.g. Koltze, Souchkov 2011); the engineer tries to improve a parameter of a system for a certain reason, but unfortunately another parameter of the system gets worse.

In the case of said door, the problem may be formulated as a contradiction as follows:

> If the gap between door and door frame is small,
>
> Then the door will close well,
>
> But a finger may be squashed in between.

This basically states that an engineering choice, the use of a thin gap, was made in order to have a door that closes well, but that this may lead to injuring people. Thus the problem situation is well defined, and could be solved using respective TRIZ problem solving tools. For the present investigation a range of different closed problems were used.

Open problems

In contrast to this an open problem, in the context of this investigation, describes a problem situation in which the problem parameters are not well defined. Typically, those situations are encountered in an industrial environment when looking for “the next generation” of a product, or for general ideas of how a project could be improved. To keep with the example of a door, an open question could be formulated as follows;

> How would the next generation of our door range look like?

Here, apart from the time scoping, where next generation probably means within the next few years, and from the topic scoping, it has to be a door, no restrictions are given, rather new functions or new implementations of given functions are looked for. For the present investigation a range of different open problems were used.

Methodology

For finding solutions to open or closed problems a selection of the 40 Inventive Principles from the TRIZ toolbox was used. The 40 Inventive Principles and their application to problem situations is an easy to grasp way of working that can be taught within a short time span and can be applied easily to both problem categories.

A selection of 10 easy to understand Inventive Principles was made as this allows for less time to teach the basic way of working, and also less distraction on the part of the user as he or she only has to choose between 10 options, and not between 40.

Table 1: A list of the 10 used Inventive Principles

#	Inventive Principle
1	Segmentation
2	Taking out
3	Local quality
7	Nesting
10	Preliminary action
13	The other way round
15	Dynamics
17	Another dimension
22	Blessing in disguise
25	Self service

The inventive principles were described in a concise form. For 30% of the participants they were presented in a card format, for the remainder of the participants they were printed out on A4 sheets.

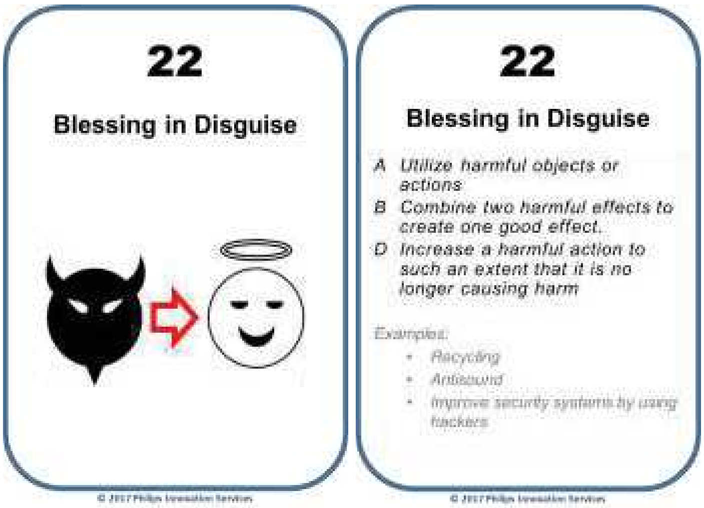

Figure 1: The card format for one of the inventive principles is shown

The way of solving both, open or closed problems using the inventive principles followed a simplified procedure compared to the classical TRIZ approach as explained for example by Altshuller et al (2005). The following steps were described for problem solving, derived from writings by Mann (2002), by Boyd and Goldenberg (2014) and by Dobrusskin (2017):

1. Describe the problem (this was given)

2. Make a list of all resources that are in or around your problem space
3. Apply the Inventive Principles to relevant resources to create ideas
4. Check if the ideas are feasible and, in the case of open problems if they are wanted/needed by the target group, or, in the case of closed problems if they solve the problem well

This procedure fits well with the needs of solving closed as well as open problems, and also requires minimal training by the participants. This greatly facilitated the research as the way of working could be explained and the problem solution process applied by the participants in as little as 40 minutes.

The process was used by a total of 61 participants from different backgrounds. 33 of the participants took part in the investigation in the EU, 28 participants took part in the USA.

Of the 61 participants, 37% were individually asked to solve the problems, whereas the remainder was asked to work in groups. 64% of the participants were first faced with the closed question, and afterwards with the open question, for 36% of the participants this sequence was turned around. The proportion of male to female participants were 80% to 20%. Most participants were Engineers (72%) with the rest divided between Students (20%) and others (8%). Only 11% of the participants had a good prior understanding or training of TRIZ, with 33% having a little understanding and 56% having no prior knowledge of TRIZ. The work experience of the participants was distributed as follows: 50% less than 10 years, 30% between 10 and 20 years and 20 % more than 20 years.

In an initial phase the problem solving process as described above was described to the participants.

They were then given a first problem, either an open or a closed one, and had to apply the process in the course of roughly 10 – 15 minutes to create possible solutions to the problem. Once they had finished the exercise, which normally meant that they had used an average of two inventive principles, they were given a questionnaire to evaluate their perception of the process.

Afterwards they were given a second problem, if they had an open problem in the first round, they were given a closed one in the second round and vice versa. Again, they had to apply the process of problem solving and take about 10 – 15 minutes to create a set of possible solutions to the second problem. Once they had finished this exercise, they again were given a questionnaire to evaluate their perception of the process, and in addition they were also asked to compare their perceptions of the first and the second problem solving exercise.

Throughout the exercises the participants had a free choice as to which inventive principle they applied. No formal evaluation of the value or quality of the created ideas was applied.

Results

The participants were positive about the helpfulness of the 10 Inventive Principles for finding solutions for both, open and closed problems. Opinions that were mentioned included the following:

- A good step for starting solution creation
- Looking forward to using this in projects
- TRIZ is systematic…

Responses to four survey questions that clarify the opinions of the team member with respect to the clarity and the helpfulness of the TRIZ principles are shown in Table 2. The table includes the question asked, mean values (M) and standard deviations (SD). Scoring is on a scale of 1 to 4 whereby 1 equals not clear / helpful at all and 4 equals very clear / helpful.

Table 2: Responses to two survey questions that clarify the opinions of the team member with respect to the clarity and the helpfulness of the TRIZ principles.

Question	M	SD
How clear were the TRIZ principles for use with closed questions?	3.11	0.45
How clear were the TRIZ principles for use with open questions?	3.13	0.65
How helpful were the TRIZ principles for the use with closed questions?	3.16	0.58
How helpful were the TRIZ principles for the use with open questions?	3.18	0.57

Responses to two survey questions that clarify the opinions of the team member with respect to the first hypothesis that formed the starting point of this investigation are shown in Table 3. Questions, mean values (M) and standard deviations (SD) are shown. Scoring is on a scale of 1 to 4 whereby 1 equals very challenging and 4 equals not challenging at all

Table 3: Responses to two survey questions with respect to the first hypothesis of this investigation.

Question	M	SD
How challenging was it to work on the exercise with the closed question?	2.11	0.58
How challenging was it to work on the exercise with the open question?	2.10	0.65

Table 4 shows the responses to two survey questions that clarify the opinions of the team member with respect to the second hypothesis that formed the starting point of this investigation. The table includes questions, mean values (M) and standard deviations (SD). Scoring is on a scale of 1 to 4 whereby 1 equals not at all fun and 4 equals a lot of fun.

Table 4: Responses to two survey questions with respect to the second hypothesis of this investigation.

Question	M	SD
How fun was it to work on the exercise with the closed question?	3.44	0.54

How fun was it to work on the exercise with the open question?	3.25	0.57

Responses to a control question asking the participants to directly compare both the aspects of easiness as well as the aspect of enjoyment of the exercises are shown in Table 5. The questions asked, mean values (M) and standard deviations (SD) are shown. Scoring is on a scale of 1 to 5 whereby 1 equals that the closed question was experienced as much easier / more enjoyable and 5 equals that the open question was experienced as much easier / more enjoyable.

Table 5: Responses to a control question are shown.

Question	M	SD
Which exercise was easier to do?	2.84	1.19
Which exercise was more enjoyable to do?	3.69	1.01

Comparing the results of the engineers with those of the students, of the male participants with those of the female participants and of the participants with lots of work experience with those with little work experience did not bring to light any statistically significant correlation on any of the survey questions.

Discussion and conclusion

The results shown in Table 2 indicate that the chosen methodology, the use of the selected 10 Inventive Principles from TRIZ, was seen as equally clear and helpful for creating ideas for closed and open problems.

Both of the stated hypotheses have been supported by the survey results. With respect to the first hypothesis (i), the responses as shown in Table 2 indicate that the participants see virtually no difference in how challenging they think it is to find solutions to closed questions vs. finding solutions to open question. The control question in Table 5 indicates that participants saw the closed questions as slightly easier to solve – and thus less challenging, however this difference is not statistically relevant.

With respect to the second hypothesis (II), the response as shown in Table 3 indicates that again the participants see little difference in how fun they think it is to find solutions to closed questions vs. finding solutions to open questions. The slight preference of 0.2 points in favor of the closed questions is statistically not relevant. This is further supported by the control question as shown in Table 5, whereby a slight preference is indicated for the open problems to be more enjoyable to work on – again, this difference is not statistically relevant.

There are a number of weaknesses of this study that should be mentioned:

Firstly, the participants were drawn from a pool of widely different ages, backgrounds and experiences. While currently TRIZ is not commonly taught in the context of a University education or the like, but instead later on during an engineer's working life, a more homogenous sample group, drawn for example from within a University context may be preferable.

Secondly, the evaluation focused purely on a self-evaluation of how the participants experienced the process of problem solving, and did not take into account the actual results they achieved. In order to evaluate if it is better for the teaching process to start learning a problem solving technique using open or closed problems, it may however be important to include some qualitative evaluation of the achieved results.

Thirdly, the problem solving method chosen may not be the optimal one. While the employed problem solving methodology based on the 40 Inventive Principles is, in the author's experience, simple to learn and powerful in application, other methods such as a Substance – Field Method suggested by Belski (2007), or the six sigma set of tools that come from the quality movement, may be equally or even better suited to fit a more experienced engineer or student. In addition, such a methods may already be included in the curriculum of an engineering study. Furthermore, problem analysis and -solving techniques have been developed that deal specifically and exclusively with either open or closed questions, and those may also be a better choice for further investigations – even if it may necessitate a lengthening of both the training of the technique, and the time allowance for solving the problem.

The results of the survey show that the problem solving process with respect to solving closed problems and open problems is experienced as equally challenging. Furthermore, there is also experienced an equal level of enjoyment when solving either closed or open problems. Notwithstanding the weaknesses of the study, this may indicate that it is not crucial to the learning process whether the teacher chooses either a closed or an open problem for teaching problem solving techniques.

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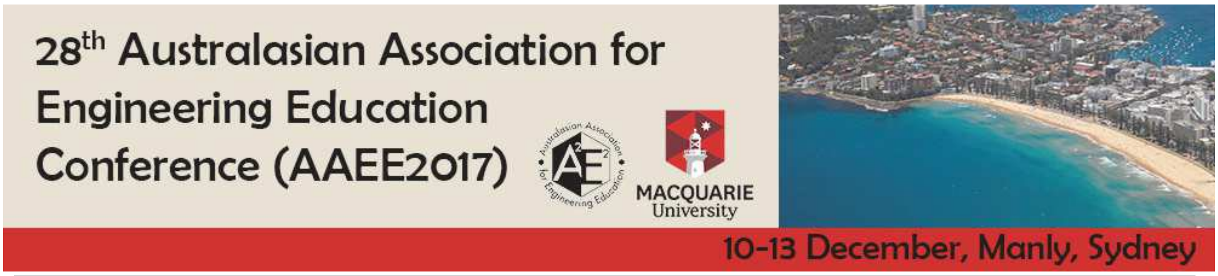

Changing Role of Modern Engineers and Social Responsibility

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SESSION

C4: The role and impact of engineers and the engineering profession in the wider community

CONTEXT

The role of modern engineers is constantly changing. It is argued that a focus on employability alone is not sufficient to prepare socially responsible engineers as it fails to address t social issues and challenges of wider society. By examining case studies, paper provides analysis of the challenges in engineering discipline.

PURPOSE

The purpose of this paper is to highlight the importance of the social sciences in helping engineers understand the context in which they will work and how it both constrains and enables their capacity for social responsibility.

APPROACH

The framework used for this paper is case study analysis. This paper critically examines few case studies that highlights how engineering knowledge has been used for addressing social issues and empower rural areas to create self-sufficiency.

RESULTS

The results that will assist to broadened the focus on the social structure and the way it enables and constrains socially responsible in engineering education.

CONCLUSIONS

This paper provides an analysis of the challenges in integrating social responsibility in engineering education that can be used by educators wanting to pursue this direction.

KEYWORDS: Social Responsibility, Engineering Education, Modern Engineers

Introduction

With the changing societal landscape, engineers are increasingly being called on to embrace responsibilities of serve the public and understand the social context of their work. This may be termed as “Modern Engineers” or the “New Engineers” (Zandvoort, 2008), who have social responsibilities and act as potential enablers in the society. They are enablers who constantly deal with the uncertainty and competing demands from clients, governments, environment and landscape of society.

The reasons behind the demand for Modern Engineers are critically examined and it is argued that a focus on employability alone is not sufficient to prepare the future generation. It is not about looking at the economic profitability of the organization but also the sustainability and the wider social context in which engineers’ work. The spectrum of activities of modern engineers span from diverse range of stakeholders to be engaged in the engineering process to the social contribution for addressing social issues in the community. It is argued that focus on employability alone will not equip engineers to be socially responsible to work in the current structure and society.

The demand for the modern engineers is reflected in changing approaches in few of the professional engineering programmes such as Engineers Ireland, Engineering Projects in Community Service (EIPICS) at Purdue University and Creative Capability Building in Massachusetts Institute of Technology (MIT). These programs have changed accreditation criteria to include outcomes focused on ethical standards and responsibilities towards people, environment and society.

The programs and educational system that reflects above engineering program are very rare. Is our wider educational system are preparing modern engineers? It is argued that the focus of education should be broadened to include social structure and the way it both enables to connect the engineering knowledge and social responsibilities. There is a call to refocus on our educational pedagogies and the engineers’ attitudes towards the systems of regulation and be potential enablers contributing to social cause.

It calls our education system to refocus on the attitudes of our future engineering graduates and preparing them to be potential enablers supporting social responsibilities and making a difference through their profession. Paper provides analysis of the challenges in educating social responsibility in engineering discipline by looking into few case studies.

This paper critically examines how engineering education can adequately address the demands that are to be imposed on future engineers. It argues the importance of social responsibilities in helping the engineers understand the context in which they work and enables them to contribute to the social cause. This paper critically examines some case studies that have focused engineering education in addressing social issues and provides recommendation for engineering educators if they want to perceive this path. It provides conceptual evidence and case study results that will assist in broadening the focus on the social structure and the way it enables and constrains socially responsible in engineering education. This paper provides an analysis of the challenges in integrating social responsibility in engineering education that can be used by educators wanting to pursue this direction.

Ethos of Engineering Education

The role of modern engineers is constantly changing with the change in the government, cliental demands and real world social issues. It requires a new skillset of social science, human relationship as well as technical competence (Mills & Treagust, 2003). While coping with the continual technological and organizational change in the workplace, engineers are trying to incorporate social and human skills in their professional practice. Despite these challenges, the predominant model of engineering pedagogy still remains “chalk and talk”, with large class size, lecture based delivery and teaching core engineering subjects (Mills & Treagust, 2003). There is very little scope for inter disciplinary teaching or incorporating knowledge from other areas such as sociology, social science, creative industries and community services. Moreover, lecture based teaching does not advance problem solving skills or critical thinking ability or prepare students for the real- life problems they will face as professional modern engineers.

Traditional engineering education is deductive, beginning with theories and fundamentals, progressing to the applications of those theories. Starting with the core principles of engineering and working down to the applications of those principles that is already understood (Felder, 2002). One problem with the deductive teaching is that it gives seriously misleading impression about the real world which the students are going to face in the future. Unfortunately, students never get to see the real process, they start with a false scenario and extensive trial and error efforts that eventually leads to an excellent presentation. Moreover, students learning is also very different. Some students learn by seeing and hearing; reflecting or acting; reasoning and intuitively; aligning to the real scenario or memorizing and visualizing. On the other hand, most of the engineering education is deductive in nature. Some instructor use lecture based teaching, others demonstrate and discuss and other use project based learning.

As an educator, how are we preparing engineers for the future and making them responsible for their sustainable career? Are we equipping the new generation with skills and knowledge to tackle most pressing issues facing society along with the technical fundamental knowledge? The engineering education needs to become more proactive to the needs of tomorrow’s job market, preparing students for the new, complex challenges they will be facing in the future. From our current teaching styles, we are preparing our students to purse corporate jobs after graduation, but they also must be aware that alternative (Example, jobs in non-profit organization) career pathways are available. Acquisition of technical knowledge is important, but it is inadequate if not retrieved and connected to the real-world conceptions. To integrate the new expectations of modern engineers to the existing one, thorough reconstruction of education system is necessary. In recent years, the engineering profession and the bodies responsible for accrediting engineering programs have called for change (Perrenet, Bouhuijs, & Smits, 2000).

The entire ecosystem of engineering educators including career advisors, internship, coop educators, and career fair needs to adopt a student-centered approach that helps students prepare for both traditional and non-traditional career pathways (Mehta & Gorski, 2016).

Engineering and Social Responsibilities

In engineering education is a demand for a broader education for modern engineers including sociology and social science. There is a broad agreement that like any other education, engineering education should prepare graduates for social responsibility (Zandvoort, 2008). As Conlon (2008) mentions, focus on employability alone will not equip engineers to be socially responsible because it fails to reflect the current structure of work and society. Some research and academia are in agreement that there is a task for educators to prepare graduates for social responsibility but there is a very little clarity on what social responsibility entails and how it impacts the curriculum to prepare modern engineers equipped with social responsibility.

The importance of social responsibilities among engineers raises questions as to whose problems engineers are trying to solve. In most education institutes, the graduates are prepared to be absorbed in corporate role and tend to use business consideration as criteria for decision making. Engineers are mainly focused on productivity they do not see the fair distribution of the benefits of economic activity as their concern (Johnston, Gostelow, & King, 2000). Generally, public perception of the engineers does not include the recognition that engineers are engaged with society and community issues (Mills & Treagust, 2003). To realise their full potential to positively impact society and individuals, it is important that engineers are socially responsible.

The technical competencies in engineering profession is important, but so is the mindset of way of seeing the world, thinking and doing unique for social and sustainability of the community. Currently, the engineering education is focused on teaching maths, physics and programming to prepare students for careers in solving specific kinds of problems (Mehta & Gorski, 2016). Real life challenges often cannot be solved with just this professional knowledge. These calls for engineers to have sense of social responsibility and extend beyond the understanding of the social implications to their project.

In a rapidly changing technology and globalization world where societies and problems are increasingly interconnected, career paths are rapidly changing to meet the new demands of society. Engineers are working on the real - world life social issues faced by communities in their day to day life. The contribution of engineers in various fields have always been motivated by the idea that their inventions would be useful to the society, yet engineering field is not viewed by the general public as a care giving profession (Mehta & Gorski, 2016). Today’s, modern engineers are designing products that empower people in less developed countries, they are building future capabilities and educating the next generation of engineers.

Modern engineering profession focus on the relationship between their professional contribution and the impact in the society (Conlon, 2008). Academics and educators need to define strategies to better connect student’s technical knowledge and build modern engineers eager to engage with higher education to solve global challenges (Ruyle, Boehm, & Lagoudas, 2016). There are few excellent models in engineering education for engaging students in practical problem solving and providing solutions for communities in the developing world such as Engineering Projects in Community Service at Purdue University, India’s Barefoot College, Engineering for Change and Creative Capacity Building Workshops by MIT.

Case Studies

This section examines the new model of engineering education and provides recommendations for adequately addressing the demands that are to be imposed on future engineers. It emphasises the importance of the social science in helping engineers prepare for the future workplace and enables their capability for social responsibility.

Barefoot College

Barefoot College challenges the whole pedagogy of engineering education, the prestige associated with paper degrees and some of the artificial constructs that create hierarchies of learning. Barefoot architects, engineers, health workers and technical specialists in the energy and water sectors receive practical training at the college and then return to their communities to promote human and infrastructural development. The main mission is to disseminate the knowledge throughout the rural communities around the world, accomplishing what many less comprehensive approaches have failed to achieve (www.barefootcollege.org). It is a unique way of empowering community and transformation into a self–sustainable society.
Barefoot college is a voluntary organization started by started by social activist, Bunker Roy. Since then, it has spread to more than 70 countries especially in Africa, Latin America and Southern Asia. Some of their project includes, The International Solar Training Program (India), Women Barefoot Solar Engineers (Africa) and Rural Women Light Up Africa, where trainees are often illiterate or semi-literate mother / grandmothers who maintain strong roots in their rural village and play a major role in community development. It is a unique model of using engineering and technical knowledge to address social issues (http://spectrum.ieee.org/energy/renewables/barefoot-matriarchs-take-on-indias-electricity-gap.

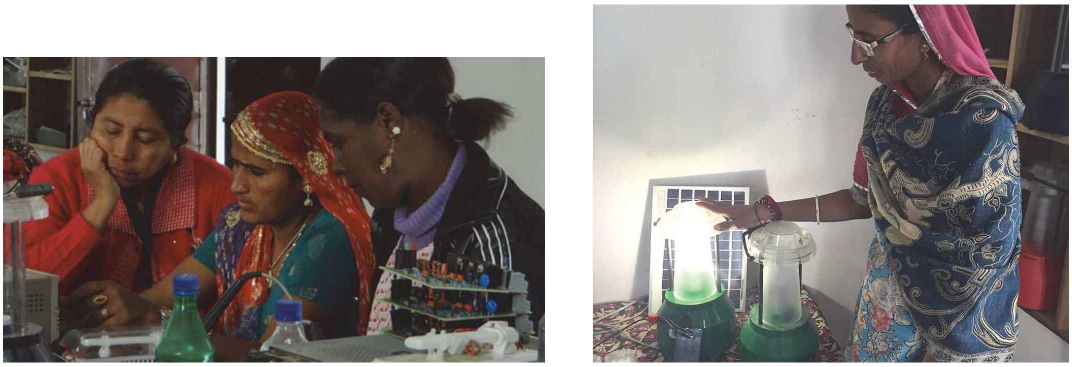

Figure 1: Some Projects of Barefoot College

Engineering Project in Community Service (EPICS)

EPICS was found at Purdue and introduced at Princeton University by co-founder Professor Ed Coyle. EPICS is a unique program in which teams of undergraduates are designing, building, and deploying real systems to solve engineering-based problems for local community service and education organizations. Students enrolling in this course earn credits by using their expertise to make a difference in the community. At the beginning of the semester, students choose one of the three existing projects and teams meet and work on that project throughout the academic year (https://kellercenter.princeton.edu/learn/epics/overview).
The main objective of the project is to provide graduates experience of real problems face by the communities and also develop a sense of social responsibilities among future engineers. It provides exposure to students with strong technical backgrounds and to take advantage of technology to improve, coordinate and deliver the services in the community. Modern engineers face a future in which they will need more than solid expertise in their discipline to succeed. They will be expected to work with people of many different backgrounds to identify and achieve goals. They need educational and social experiences that can help them broaden their skills.

The EPICS team is engaged in a number of projects throughout the academic year and students have the opportunity to select the one that best fits their interests. Some of the projects includes, Automated Tour Guide (disability center project), Deaf Kids Code Project and aero and Astro Engineering project. Most of the projects are collaborated with industry partner and community organizations.

Engineering for Change (E4C)

The main mission of Engineering for Change organization (https://www.engineeringforchange.org/who-we-are/) is to improve the lives of underserved communities by better preparing the global development workforce, optimizing the solutions development cycle, and ensuring public health and safety. It collaborates with external partners that share similar mission and passion for improving the quality of life. It is a multidisciplinary coalition between engineers, industry partners and the community helping global development practitioners to design and deploy fit-for-service solutions that address quality of life challenges.

Engineering for change breaks the barriers between the tertiary education, industry partners by provoking new ways of thinking in addressing the problems of the society. It promotes an interdisciplinary practice where practitioners integrate their technical training with an understanding of economics and business, social science and politics to benefit people living in poverty. It is a community of individuals who believe that engineering can change the world for the better.

E4C, works in partnership with various industry partners and engineering community such as Engineers without Borders (USA) and IEEE, helping them develop knowledge and re-invent method design. Projects are from wide range of areas such as water, health, sanitation, ICT and Energy.

Figure 2: Examples of E4C Projects

Discussion and Recommendation

There are several relevant insights from the above exemplars that are worth sharing at an educational conference. The core message is that engineers can pursue careers in the either corporate or social impact area, but they more likely to be successful if they understand the nature of these careers and the professional competencies (Mehta & Gorski, 2016). For example, a software engineer tasked with designing a new software / App for food delivery system, but engineer must combine this with problem solving mindset to ensure the food is delivered on time and is fresh, understand the traffic system of the area, knowledge of human emotions associated with food, motivating factors of users and cost analysis. So, it is the overall social factors that needs to be considered along with the technical skillsets.

Research suggest that the engineering education needs to widen its focus if students are to be educated as socially responsible engineers. Focusing on the skills and values of individual students related to their employability in the corporate world is not adequate to prepare them for the challenges of the real world that they are going to face (Conlon, 2008). While there are, programs initiated by few universities and private institutes where students study problem solving, there is a need for a long-term community or social based problem solving educational system (Ruyle et al., 2016). Engineering Education system needs to become more proactive to the needs of the tomorrow's job market and prepare students for the new, complex and interdisciplinary challenges that they are going to face.

A growing number of students want to experience and leverage their engineering education and focus their career where they can directly see the impact of their knowledge in the society. The impacts of these changes will alter the way we teach in engineering education. Students may undertake community led or engaged projects that are real and empower communities in the longer term. It is essential to move beyond academic delivery methods and considering partnering with communities. As an educator, it is a challenging journey to set away from the core engineering principles and align with the social and community values.

How do the educational institutes rise up to this challenge and prepare graduates for the future?

What advice do we have for the educators and universities for building the next social innovators?

The recommendations presented below are some of the guidelines of how engineering education can be reframed to prepare graduates as problem solvers and social innovators for the rapidly changing world.

1. *Teaching Pedagogy of Engineering Education*

   The skillset and the understanding needed by modern engineers, it would appear that these demands are unlikely to be satisfied by a traditional engineering curriculum and "chalk and talk" pedagogy. The curriculum needs to address more than just technical skillsets such as ethos, attitude, pathos, emotion and social responsibilities. A mixed approach with some project based learning and integrating with multidisciplinary areas, appears to be the best way to satisfy industry, social and community needs without sacrificing the core skillset of engineering fundamentals.

2. *Building External Relationships*

   Forming a partnership and building strong relationships between business, technology, community and non-profit organizations, broadens the understanding of students. Participation in community and social projects benefits social responsibility attitudes of the students. Educators can stress the importance of networking especially in non-traditional field (Ruyle et al., 2016).

3. *Encourage Interdisciplinary / Cross disciplinary Projects*

   Most of the creative industry hopes universities will offer programs focused on interdisciplinary, collaborative sharing of knowledge in which students tackle real problems and develop innovative solution (Mehta & Gorski, 2016). Although almost all departments in the universities work in silos. In real world, most of the social innovators are from a range of disciplines working together towards a common goal. In educational institutes, by creating interdisciplinary projects, educators can get students to think beyond their traditional career paths and bring new values in different domain. As a result, we are creating “T” shaped graduates who are well versed with many disciplines and capable of providing innovative solutions to a complex problem.

4. *Preparing Students to be Systems Thinkers*

A thorough understanding of both theoretical and operational level will help students to improve and develop thinking beyond their career path. Social and community development involves wicked challenges that needs understanding of interconnected world. Exposing students to intangible, large and complex problems that exist in the society, educators can encourage them to think creatively and challenges their thought process.

5. *Ethical and Social Responsibilities as Part of Learning Process*

Our current education is mostly focused on preparing graduates for corporate employability. For modern engineers, we need to broaden our educational system and see that engineering graduates are adequately prepared for the social responsibilities and contribute to the future generation. As Bucciarelli (2007), says that is not just a more expansive reading of the code of ethics, but need a substantial reform of engineering education across the board to enable more expansive and critical study of engineering, including social and political dimensions (Bucciarelli, 2007).

6. *Social and Community Focused Projects*

In order for modern engineers to realize their full potential to beneficially impact society and individuals, it is important that they work on social and community. It creates a sense of obligation and duty to perform to benefit society, the environment and the economy. Studies have proved that, students who have participated in social or community projects are more likely to cite engineering courses as contributing to their views of social responsibility compared to students who haven’t participated (Bielefeldt & Canney, 2014).

7. *Keep it Real*

Educators can help students to understand what is actually practical and how they can use their technical knowledge to address complex challenges in the community by providing real projects. Student needs to be solving complex problems creatively, but at the same time understand that one idea that you come up in classroom is unlikely to be practical in real world. A significant amount of work, creativity, people, and resources are needed beyond their idea before they can have a large impact. Getting exposure to the reality of the competitive world can help students be more practical when they enter the workforce.

Conclusion

In the above we have seen that engineering education needs to widen its focus if students are to prepared for the future as a socially responsible engineer. A narrow focus on the technical skill and knowledge of individual students related to corporate employability is not adequate for modern engineers. Graduates need to develop the capability to relate their individual practice to the wider society. This has been practices in few programs and institutes but need to be integrated in the tertiary and wider engineering education. Educational institutions need to rise up the challenges of preparing graduates for the future.

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A Flipped Classroom with Low-stakes Assessment to Maintain Student Engagement and Integrate Theory and Practice

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SESSION Integration of theory and practice in the learning and teaching process

CONTEXT We report on the use of a flipped classroom for an undergraduate course in Digital Systems in which weekly, low-stakes assessment is used to: encourage continuous engagement and provide continuous feedback; provide opportunities to apply theory to practice and to obtain meaningful assistance; and establish practices and incentives so that students can take responsibility for their own learning. Class records and student evaluations for the past 5 years show very high levels of attendance and student satisfaction. In this paper we evaluate the effectiveness of the approach more deeply. We also reflect upon the experience of teaching the course and consider its resource implications.

PURPOSE The purpose of this study is to determine to whether the low-stakes assessment of preparation and progress effectively contributes to student learning, and whether the flipped classroom succeeds as a platform for connecting theory and practice.

APPROACH In 2013 the course was changed from a conventional lecture series to a flipped classroom in which students prepare for their weekly class by reading, watching recorded presentations, and attempting exercise problems. During class, students work individually and in small groups on problems that are more open-ended and may require discussion in small groups, searching for solutions or resources, or practical design and implementation. Attempting the preparation and class work is sufficient to be awarded the marks for the tutorial. Student evaluations and results since 2010, as well as a dedicated survey administered this year, have been used to evaluate the effectiveness of this approach.

RESULTS Student evaluations show a statistically significant improvement in reported attributes including development of thinking skills, effective feedback, and overall satisfaction with course quality. Students' opinion of the workload has not changed, with over 97% agreeing that it was appropriate before and after the change. Flipping the classroom has not had a significant effect on exam results, which were appropriate before the change. An anonymous online survey was completed by 92 students who recently completed the course. 98% agreed that the course helped them understand the connection between digital systems and practice, and 93% agreed that marks for the tutorial encouraged them to attempt the preparation.

CONCLUSIONS The flipped classroom with low-stakes assessment recieves positive student evalutions and is a satisfying teaching experience for the lecturers with a workload no greater than that accounted for a conventional lecture course in the authors' school. Most students find the low-stakes assessment a useful motivator, prepare appropriately for tutorials, and agree that the flipped classroom facilitates development of both theoretical understanding and practical skills.

KEYWORDS Flipped classroom, Low-stakes assessment, Assessment for learning

Introduction

Although there are various definitions of a flipped classroom, most share the notion that students prepare individually before class, and work interactively in groups during class time (Bishop and Verleger, 2013). There are many potential benefits to this approach and it has received a lot of attention in recent years. A 2015 survey of 1089 college faculty, mainly from North America, found that 75% had tried a flipped approach (Faculty Focus, 2105). But the flipped classroom is not without pitfalls. The same survey found that 5.5% of respondents would not try the approach again.

In 2013 we flipped the classroom of a third year course on Digital Systems at the University of Adelaide. The existing course used a format that was typical in our school at the time, with 3 lectures a week and fortnightly class tutorials. Neither student satisfaction nor achievement were problems, as the course was rating well in student evaluations and grade distributions were within appropriate bounds.

Nonetheless, we had several motivations to make a change. Key among them was a desire to give students more experience with open-ended design problems, and more opportunities to put theory into practice. We were also inspired by the promise of a pedagogy that would develop independent, student-centered learning, and also would provide meaningful support for students when they need it.

The change has been a success with the flipped classroom providing many more opportunities for active and collaborative learning in which theory is applied to practical problems. Student satisfaction has improved, student achievement has remained high, and students agree the workload is appropriate. More details are provided in the Evaluation section.

Aware of some of the pitfalls in flipped classrooms, we introduced weekly low-stakes assessments. These provide incentives for students to maintain engagement with the course, prepare before classes, and complete class work. We believe they have been critical for the success of the course. To better understand student attitudes to the weekly assessment, and the flipped approach more generally, we issued an online survey to students who completed the course in Semester 1 2017. The results of this survey are also presented in the Evaluation section.

Context

Flipped Classrooms

For their survey of the research into flipped classrooms, Bishop and Verleger (2013) chose to define the flipped classroom as “an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom.” This definition is helpful for explaining the appeal of the approach. Using technology it is possible to shift teacher-centric or didactic learning activities online so that students can complete them at their own pace, at times that best suit them. This frees staff time for student-centered learning, which happens best face-to-face. If good quality lecture recordings are available, then flipping the classroom is a ready opportunity to expand the student-centric aspects of a course and thereby employ some of the many well-established student-centric paradigms such as peer-assisted learning, problem-based learning, and active learning.

The Faculty Focus (2015) survey of teachers who had tried flipped classrooms reported that: 75% of respondents saw greater student engagement; 55% saw evidence of improved learning; and 80% said students were more collaborative.

Case studies reporting the effects of flipping a particular course have been published for a wide variety of disciplines. For example, within our own discipline, Papadopoulos & Roman (2010) reported faster progress and improved test achievement for a flipped course in electrical engineering. Of particular relevance, Warter-Perez and Dong (2012) flipped a class to “embed inquiry and design projects into a digital engineering lecture”. These motivations have much in common with our own. They reported that the change improved students’ understanding and design skills.

Not all studies report unqualified success. A carefully controlled study of an undergraduate civil engineering course by Hotle and Garrow (2016) found that quiz performance did not change significantly, and that students take time to adapt to the flipped format. The authors caution that, “the method could increase the frustration of weaker students at the beginning of the course.” They also find that the inability of students to ask questions during the recorded lectures is a critical issue and that most of the questions asked in class were related to the class problems, not the lecture material. Our response to this concern has been to ensure that the lecture-material and the in-class activities are well aligned. If the class activities require direct application of the lecture theory then questions about one will help understanding of the other.

A second concern about flipped classrooms is that it “undervalues the power of good, engaging, face-to-face Socratic teaching” (Hamdan, McKnight, KcKnight and Arfstrom, 2013). This is reflected by one professor’s response to the Faculty Focus (2015) survey:

> *Students wanted me to lecture, tell stories, ask questions, and stimulate discussion. They did not want to try and learn the material themselves. They did not feel empowered. They did not see me as a co-participant. They wanted me to be in charge.*

Our observation is that the flipped classroom is not mutually exclusive with Socratic teaching; quite the opposite with the small group classes providing a much better forum for meaningful discourse than large lectures.

A challenge of particular relevance to this study is clearly expressed by Faculty Focus (2013):

> *one consistent area of concern among faculty is student motivation. The attitude seems to be that if students don’t do “traditional” homework assignments that involve reading, writing, and preparing for class, what makes us think they would watch a video or prepare for class using different approaches just because we call it a “flipped” classroom?*

We shared this concern when we planned our flipped class and turned to principles from ‘assessment for learning’ to address it.

Assessment for Learning

For our flipped classroom to work as we intend it is critical that students prepare before classes. They require a baseline of knowledge to be able to attempt the class activities, and they need to know what they don’t understand so they can seek assistance. It all hangs on the students taking sufficient responsibility for their own learning to spend time preparing outside of class.

Development of self-managing, reflective learners is one of the goals of ‘assessment for learning’ (Broadfoot et. al. 2002):

> *Assessment for learning is the process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go and how best to get there.*

To be able to decide where to go, and how to get there, a learner needs clear goals and appropriate feedback. Nicol and Macfarlane-Dick (2006) formalise this process in a model of 'self-regulated learning' and describe seven practices of good feedback to support it.

For our flipped classroom we introduced weekly low-stakes assessments of preparation and class work to give students the necessary incentive and feedback to become self-regulated learners. Further details of the assessments, and their relationship to Nicol and Macfarlane-Dick's seven practices are provided in the following section. The effectiveness of the scheme is considered in the Evaluation section.

Course Design

In 2013 we flipped the classroom of our established third year undergraduate course on Digital Systems. The new course satisfies Bishop and Verleger's (2013) definition of a flipped classroom with weekly interactive face-to-face classes and individual computer-based preparation before classes. Using their classification the new course is fully flipped, with in-class activities consisting of small-group activities and homework (individual activities), and out-of-class activities consisting of video lectures, reading, and homework exercises.

In the flipped format each student attends a 2-hour class once a week. A lecturer and a tutor are present at every class and spend time individually with every student. The class instructions specify preparatory lectures, reading and exercise questions that focus on foundation theory and skills. The in-class exercises are more open-ended and may require discussion in small groups, searching for solutions or resources, or practical design, simulation and implementation using computers and reconfigurable logic circuits. Classes also include a mini-lecture or discussion focusing on an aspect of the course the students are finding challenging.

This arrangement is intended to promote the integration of theory and practice by building the foundations of theoretical understanding in pre-class preparation; then consolidating understanding and integrating it with practice in the class. The course learning outcomes and learning activities are carefully aligned to ensure this works. The learning outcomes are expressed in terms of practical capabilities and the learning activities involve direct application of these capabilities. For example, one of the Digital Systems learning outcomes is to "be able to design, build and test digital logic for systems of moderate complexity using common digital components, schematic diagrams, and hardware description language." This outcome is the focus of a number of weeks in the course, each of which involves design and analysis of a digital logic system for preparation, and then implementation, testing and simulation in the class.

Digital Systems is an ideal topic for learning about design. The underlying circuit technology is well understood so that students can focus on big picture challenges such as designing power efficient architectures. Systems of moderate complexity can be quickly realised in reconfigurable hardware. This provides an excellent training ground as students can see their designs in action, experiment with alternatives, and appreciate the applications of the skills they are developing. For our flipped classroom, to give the students more opportunity to practice and experiment outside of classes, they are loaned a reconfigurable logic development board for the duration of the course. They bring these to classes and work in groups to build useful systems. They can also use them in their own time, at home or in the university computing suites, either to finish the assessed tutorial questions or just for practice.

During the class the teaching staff sit with each student individually, discuss and quickly assess their preparation, and provide help as required. They take every chance to branch into a broader discussion about design or engineering practice. Students keep an exercise book in which they record preparation exercises, tutorial problems, lecture notes and practice problems. During the one-on-one discussions the teacher stamps the student's exercise book and records a mark for preparation and another for completing the exercises from previous class. Full marks are given for attempting all the problems, and checking the answers against the published solutions. The marking is not time consuming and only contributes 15% of the final grade.

As discussed above, the goal of this assessment is not to drag unwilling students through the course, but to create structures and incentives to help students take responsibility for their own learning. To a greater or lesser extent, it meets all seven of the principles from Nicol and Macfarlane-Dick (2006):

1. helps clarify what good performance is: by having exercises and activities that are directly aligned to the learning outcomes and typical of questions in the summative assessment.
2. facilitates the development of self-assessment (reflection) in learning: students check their own answers against published solutions and seek assistance when they cannot reconcile the differences; some exercises every week explicitly require reflection on learning.
3. delivers high quality information to the students about their learning: teachers provide timely face-to-face feedback on progress and achievement.
4. encourage teacher and peer dialog: using small group activities that involve explaining concepts to peers, and during one-on-one discussions with teachers.
5. encourage positive motivation and self esteem: by having "frequent low-stakes assessment tasks, with feedback geared to providing information about progress and achievement, rather than high-stakes summative assessment tasks where information is only about success or failure, or about how students compare with their peers" (Nicol and Macfarlane-Dick, 2006).
6. provides opportunities to close the gap between current and desired performance: by making available a large set of alternative practice exercises so that students can re-attempt challenging problems.
7. provides information to teachers that can be used to help shape teaching: patterns emerge form one-on-one discussions that indicate concepts or skills the students are finding difficult.

Evaluation

Methdology

The Digital Systems course ran for 3 years in a conventional format and 6 cohorts have now competed the flipped version. Anonymous course evaluation surveys have been issued to every cohort. The surveys use a Likert scale from 1 to 7 and the results below give combined means and standard deviations computed for the two populations. Unfortunately some of the questions were changed in 2012 so that the results for these questions from 2010-11 cannot be used for this study. Aggregate course evaluations for every course from the School of Electrical and Electronic Engineering are also available. Only statistically significant increases are claimed according to a one tailed t-test at a significance of 95%. Figures claimed for agreement indicate the percentage of students who responded with 5, 6 or 7. Primary exam results are also available for the two populations and they have been compared using a two-tailed t-test at 95% confidence.

An additional online survey was issued to the cohort of 204 students who completed the course in semester 1 this year. Once again a 7-point Likert scale was used with responses 5, 6 and 7 indicating broad agreement.

Results

Table 1 shows student evaluation responses for the course before flipping, all courses in the same school over the same interval, the course after flipping, and all courses in the same school over the same interval. Student evaluations for all questions that have been asked consistently since 2010 have improved since the classroom was flipped. In addition, for every cohort since the class was flipped, over 95% of respondents agreed that the course "has a workload that is appropriate for the achievement of its learning outcomes". Table 1 also shows that aggregate results from the school increased for the period after the class was flipped. This confounds the results and makes it difficult to attribute the improvements to the flipped classroom; however we can observe that the measures for the flipped class are all higher than those for the school over the same period.

Table 1 also shows the student evaluation results for two relevant questions that were added to the survey in 2012. For these two questions there is insufficient data prior to flipping the classroom to be able to claim an improvement with 95% confidence.

Table 1: Student evaluation responses for the course before and after flipping and aggregate results for all courses in the school over the same intervals. Results are given as *mean* (*s.d.*).

	Unflipped (2010-12)		**Flipped (2013-17)**	
Questions asked since 2010: The course…	**Course *n* = 103**	**School *n* = 1923**	**Course *n* = 223**	**School *n* = 5408**
uses methods of assessment that help me achieve its learning outcomes	5.9 (1.1)	5.3 (1.4)	6.23 (0.8)	5.7 (1.4)
helps me to develop my thinking skills	6.1 (1.0)	5.6 (1.3)	6.37 (0.7)	5.7 (1.3)
has a learning environment that takes into account student diversity	6.0 (1.0)	5.6 (1.3)	6.31 (0.8)	5.7 (1.3)
supports my learning with effective feedback	5.7 (1.2)	5.1 (1.5)	6.31 (0.8)	5.5 (1.5)
Overall, I am satisfied with the quality of this course.	6.1 (1.0)	5.4 (1.3)	6.37 (0.7)	5.6 (1.5)
Questions asked since 2012:	***n* = 29**	***n* = 749**	***n* = 223**	***n* = 5408**
has clearly identified learning outcomes	6.2 (1.2)	5.9 (1.1)	6.3 (0.7)	5.8 (1.2)
uses appropriate strategies to engage me in my learning	6.0 (1.1)	5.6 (1.3)	6.3 (0.8)	5.5 (1.5)

The average primary exam mark for the 223 students who took the course prior to flipping was 65% (17%); for the 553 students who have completed the flipped course it is 63% (18%). There is no statistically significant change and the marks distribution was appropriate before and after the change.

While class attendance should not necessarily be a goal in itself, in the case of the flipped class it is an indicator of engagement with the course. Total tutorial attendance for the flipped class has been 95%. Students have been awarded marks for preparation on 94% of occasions. 93% of students have attended 10 or more of the 12 tutorials.

In the weekly low-stakes assessment, half of the marks are for attempting the preparation, and half for completing the previous week's in-class questions. Four questions in this year's survey explored student attitudes towards this assessment. The results are summarised in Table 3. Over 93% of respondents agreed that the marks encouraged them to attempt the preparation and the in-class questions and over 93% attempted almost all or all of the questions most of the time. The results also show that there are a few respondents who were not encouraged by the marks.

Did students prepare effectively for classes? Importantly, all but 3 of the 92 respondents to the survey agreed the preparation questions helped them achieve the learning outcomes. 80% of respondents listened to the recorded lectures frequently or more often, and over 94% agreed they helped them achieve the learning outcomes. The questions about the textbook reveal a variety of study habits. Over 20% of students read the textbook weekly as part of their preparation; 12% never read it. Presumably, between these extremes students dipped in to the book when help was required with over 70% agreeing that it helped them achieve the learning outcomes.

Table 3: Survey results for questions related to low-stakes assessment. 92 respondents.

	always \ strongly agree \ all of them	usually \ mostly agree \ almost all of them	frequently \ slightly agree \ just more than half	about half the time \ undecided \ about half of them	occasionally \ slightly disagree \ just fewer than half of them	seldom \ most disagree \ almost none of them	never \ strongly disagree \ none of them
Questions related to low-stakes assessment							
The tutorial marks encouraged me to attempt the preparation:	57	18	11	1	2	2	1
How many preparation questions did you attempt most of the time?	45	41	5	1	0	0	0
The tutorial marks encouraged me to attempt the in-tutorial questions:	53	21	15	1	1	0	1
How many in-tutorial questions did you attempt most of the time?	43	44	3	2	0	0	0
Questions related to preparation							
I listened to the week's recorded lectures before coming to the tutorial:	37	27	10	11	3	2	2
The recorded lectures helped me achieve the course learning outcomes:	29	44	14	3	2	9	9
I read sections from the textbook before coming to the tutorials:	19	12	14	13	12	11	11
The textbook helped me achieve the course learning outcomes:	19	27	19	13	8	5	1
I made a genuine attempt to complete all of the preparation questions before the tutorial:	52	27	9	3	1	0	0
The preparation questions helped me achieve the course learning outcomes:	43	39	7	2	1	0	0
I took a short-cut in the preparation and copied solutions without making a genuine attempt:	1	5	5	8	20	34	18
Questions related to theory and practice							
The flipped classroom helped me understand the theory of digital systems:	29	45	10	5	1	0	2
The flipped classroom helped me learn practical skills in digital systems:	38	34	13	3	1	1	2
The course helped me understand the connection between digital systems theory and practice:	40	40	10	1	0	0	1

Over 89% of respondents usually made a genuine attempt to complete all the preparation questions. The other side of this is that there are a few students who do not take the opportunity to prepare before classes. As all the solutions are available in advance, it is possible for students to take a short cut and copy solutions without genuinely attempting the problems. 19 of the 92 respondents admitted they copied some solutions at least half the time.

The last part of Table 3 shows survey results for questions related to the integration of theory and practice in the course. 91% of respondents agreed that the flipped classroom helped them understand the theory; 92% agreed that it helped them learn digital systems; and 98% agreed the course helped them understand the connection between theory and practice.

For a cohort of 120 students, a lecturer and tutor attend four 2-hour classes a week. Once we account for lecture preparation and practical demonstrator costs for the un-flipped course, the teaching costs are only slightly higher for the flipped version, and still within the budget for a course in the authors' school. There are higher contact hours for the lecturer but in our experience this is justified by an improved educational experience for the students and a much more satisfying teaching experience for the lecturer.

Conclusions

The flipped classroom incorprating small-group exercises, design, implementation, and lecturer-led discussions has increased the focus on design and the interplay between theory and practice. Weekly low-stakes assessments maintain the course tempo and provide the necessary framework for most students to develop as self-regulated learners. A handful of students who do not grasp this opportunity, and are left behind by the process. We do not know yet if these students also achieve lower grades for the course, although this seems likely. The close interaction between staff and students in the flipped format means there is scope to identify these students early and provide assistance.

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A Problem Shared is a Problem Halved: Benefits of Collaborative Online Engineering L&T Content Development

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CONTEXT Three academics from three separate Engineering schools (Chemical, Civil and Mechanical) at a large, research-intensive public university, identified an opportunity to collaborate with an Engineering student partner, Educational Developer and Learning Analytics Manager on the design and development of blended learning resources. The collaboration focused on the development of a question bank that could be shared across the three schools to support teaching in large cohorts. This paper explores the different perspectives of all stakeholders in the project, the challenges experienced and how the team resolved them.

PURPOSE Student feedback across the three schools revealed an opportunity to provide more individualised support resources for students in large cohorts. The team considered the use of comprehensive question bank resources to meet this need. An important consideration and challenge for the team was to design feedback mechanisms that enabled students to identify and understand their misconceptions with complex fluid engineering concepts (embedded feedback), and/or receive a general solution approach to help them retry the same question.

APPROACH After a review of existing practice and a mapping of content taught in the different courses, the team reviewed several commercial off-the-shelf question bank solutions. Many of the commercial products explored were subscription-based, and had customization, content and feedback limitations that reduced the effectiveness and sustainability of the resource. Despite the effort required for the development of a new question bank, this afforded both flexibility and control of the final product.

RESULTS Based on our experience and lessons learnt, we proposed a framework for cross-school collaborative development of blended learning resources, including team composition, distribution of tasks, and tools and strategies for rapid development work, digital content management and sharing. Benefits of the project included the online resources enabling monetary resources to be reallocated to an industry-relevant design activity, thus enabling a better integration of theory and practice in the Chemical Engineering Fluid Mechanics courses. The project also identified an opportunity for shared physical lab resources between the Civil and Mechanical schools.

CONCLUSIONS Good strategies in collaborative online content development can lead to many benefits and enable the integration of theory and practice in Fluid Mechanics courses, benefiting the students as well as making the feedback to students more effective.

KEYWORDS Blended learning, question bank, cross-functional teams

Introduction

The past decade has seen several changes in engineering education (McKenna, Yalvac, & Light, 2009), including a focus on curriculum redesign (Crawley, Malmqvist, Östlund, Brodeur & Edström, 2014), students' skills development (Shuman, Besterfield-Sacre & McGourty, 2005; Walther & Radcliffe, 2007), assessment methods (Olds, Moskal & Miller, 2005) and modes of teaching (Bourne, Harris & Mayadas, 2005; Ford, Vigentini, Vulic, Chitsaz & Prusty, 2016; Mills & Treagust, 2003; Prince, 2004). These have largely been possible thanks to an increase in funding supporting innovative practice and growing pressure from the industry on universities to provide engineers that "build things that serve society" (Crawley et al., 2014) and "create the world that never was" (Von Kármán, 1994).

In a similar vein, a project was initiated by the Engineering Head of Schools and Deputy Dean of Education at a large public research-intensive university in Sydney to support academics moving their courses to blended delivery mode. Nine large courses, taught by multiple schools in the faculty of Engineering, were initially selected for re-development. Small teams of three academics were formed for seven of these courses because they covered similar content and lent themselves for potential efficiencies across the schools. This approach is not dissimilar to many other examples of integration (Evans, 1995; Froyd & Ohland, 2005). However, the focus, partly directed by institutional strategy (UNSW, 2025), was on a blended approach to learning design (Garrison & Kanuka, 2004; Porter, Graham, Spring & Welch, 2014).

Although there are several accounts of the outcomes of the innovations implemented, there are only few accounts reflecting on the process and achievements of a collaborative redevelopment project. This paper aims to fill this gap and examines the engineering design process involved in the teaching of *fluids mechanics* concepts across chemical, civil and mechanical engineering schools at the university. By examining the detailed account of one team in the project, which included three engineering academics, an undergraduate engineering student as partner, and an educational developer, we provided an insightful overview of the redevelopment process.

The Context

The project demonstrates an example of the collaboration between staff with disciplinary expertise, learning design and educational design and development skills, and partnership with students, to enhance the learning experience for students in both blended and online contexts. The teams included academic staff, educational developers, media specialists and a student partner. The Schools and Faculty of Engineering provided funding to support the redesign and development work; $15,000 was also allocated to support the employment of students as partners. Each project had a timeline of three months. The project deliverables for each course included the redesign of courses for a blended delivery, the development of a range of online learning resources (including online practice exercises, online assessments, quizzes, question banks, adaptive tutorials, lab activities, videos and digital graphics), workshops and a pilot of the Active Learning Platform (ALP - based on Echo360) to facilitate new approaches to lecturing. A significant outcome of the project was the collaboration between academics from different schools that led to the establishment of common understanding regarding the delivery of courses with similar content.

Before the project: problems and the individual contexts

Chemical Engineering Academic

According to ML, the project provided a potential opportunity to explore different teaching methods. The course had been predominantly taught in the same way over the last twenty years. Further, the school budgets have not been substantial enough to enable the exploration of different teaching methods. This project created an opportunity to re-think the approach. For this academic, the project could potentially promote the development of creative engineers that see beyond worked examples and can transfer their knowledge and skills to cope with unexpected situations. In addition, the project initiation offered the opportunity to foster capacity building, and focus on course continuous improvement and shared team effort, contributing to better quality resources. Capacity building would involve the opportunity to train school research assistants in the design and development of course resources, and the dissemination of these skills and experiences throughout the school. Continuous improvement would take the form of evaluating and improving the resources each semester through both qualitative and quantitative measures. It was also anticipated that the team effort in creating shared course resources would produce better quality resources than those produced individually. An added benefit of a collaborative project team was the peer support network that this would enable. For students, it was hoped that the outcomes of the project would enable confidence building and mastery through a dialogic construction of knowledge.

Civil Engineering Academic

SF saw Fluid Mechanics as one of the most challenging courses for his second-year civil engineering students. It is a large course with 550 students and for many students the course is their first contact with the water engineering side of civil engineering. SF was interested in trying something new to improve student learning of key water engineering concepts. This project could ultimately motivate more students to get excited about water engineering. The project also presented an opportunity to connect with other academics who teach Fluid Mechanics and learn from their experiences, build synergies and cross-pollinate ideas. The academic wanted to provide students with resources where they had an opportunity to practice as much as they liked, whilst at the same time providing them with feedback. Allowing students opportunities to practice basic concepts was essential for students to fully understand basic Fluid Mechanics concepts. Common feedback from students was that they wanted to have more examples, more practice and more feedback. This could all be combined into the one project. It was anticipated that satisfied students might be more motivated to contribute actively to learning and to their classes in general. In the long run this academic hoped these students might become better engineers and problem solvers.

Mechanical Engineering Academic

For SC, the project could potentially enable an optimal and seamless integration of face-to-face teaching with digital education. It was hoped that this combination could provide the delivery of a distinctive educational experience for his students by empowering them to become the best that they can be. The project was timely in that large cohorts and physical resource limitations meant the school was replacing face-to-face tutorials with online tutorials. The project could add value to the online tutorials. The project also provided an opportunity for the academic to work with other colleagues to design, experiment and integrate the best available educational technologies into their Fluid Mechanics courses. It was anticipated that blending face-to-face teaching with digital education provides students with greater flexibility to personalize their educational experience and life-study balance. The project could potentially enable a considered integration of online technology to improve student learning through innovative use of online tutorials, question banks and online forums.

The Student View

JJ is an undergraduate who sought an opportunity to contribute to the development of the Fluid Mechanics course that he had taken during his studies. His first-hand experience meant that he could make a major contribution in supporting other students in resolving the issues he had already faced. The Fluid Mechanics courses, amongst other courses in second year, were particularly challenging, as they were a large step up in content compared to first year courses, which are generic across all Engineering streams. In addition, these courses laid the foundational knowledge for the rest of the coursework, and difficulties in these courses can lead to a poor understanding of material later in the degree program. It is therefore important to improve the learning outcomes of these subjects so that students develop into confident and capable engineers. JJ wanted to develop resources to allow students to practice engineering problems at their own pace in a structured manner. Ideally, the resources would be able to present themselves to the students at the right moment for them; then, as they built confidence, it would present them with harder problems, introducing new concepts and building on existing concepts. At each stage the student would be provided with feedback to identify particular problems that they were having trouble with to enable them to progress with the material and not feel overwhelmed. The result (not necessarily from this project alone, but from their learnings overall throughout their coursework) would be to have engineering students who can make justified assumptions, apply sound logic and reasoning, and apply engineering equations and concepts to complex problems, particularly those which have no algebraic solution.

The Educational Developer

JV has the challenging yet rewarding role of working with academics in the analysis, design, development, delivery and evaluation of their courses. This project was quite unique in that it brought three separate engineering school academics together (who had never previously met) to collaborate on one project. The project would be challenging in that team consensus would be needed in deciding on the focus of the project, whilst ensuring that it was possible to accomplish the deliverables within three months. The educational developer was motivated for the project to succeed and understood that his role was to ensure the team developed a project they could take ownership of. He understood that this would provide the best opportunity for their project to be sustainable over time. His role would be to act as a conduit for the team, linking them to internal resources where required, providing pedagogical and project coordination support. The project presented an opportunity to trial a new concept in the university called ‘students as partners,’ where funding would be provided to employ a student to be part of the project team. This would provide a valuable student perspective of the project, and avoid what the developer had coined ‘ivory tower design,’ where resources are developed without the input of the end user. The developer was interested in the insight that a student would provide to the project and whether this could be trialled in other projects.

The shared problem

After facilitating a discussion about similarities and differences of their courses, the team created a blueprint of topics and concepts that showed an overlap of at least 80% of concepts in Fluid Mechanics across the three curricula. The academics shared similar experiences related to feedback and requests from students to increase the formative elements of each course, as well as the example questions in their courses, and to provide continuous and detailed feedback on how students were going in their classes. The academics reached consensus very early in the project that support resources in the form of a question bank could potentially add value to support student learning. Given the overlap of content, all could contribute to writing questions to be shared across the three courses; however, it was imperative that the remaining 20% of content could be controlled by each academic.

The Educational Developer supported the team by acting as a conduit to connect the team members to support personnel during the project. This involved linking the team to library liaison officers to discuss copyright, assessment experts, staff with Moodle STACK question type experience and data analytics personnel. He was able to highlight strengths and weaknesses of various question bank options as well as the technical requirements to make the implementation possible. The team also spent time working out how to keep the project sustainable, for example, if future updates were required for questions in the question bank, how could they ensure they could be made by all team members easily and at no cost. One decision that enabled this was the use of Moodle learning management system (LMS), which allowed the academics to have total control of all questions in the question bank, as well as future updates of these resources. The disadvantage of this approach, however (as compared to using a commercial off-the-shelf question bank), was the initial outlay of time taken to design and develop the questions. The question bank was intended to be developed with a mix of both Moodle quiz questions for simple questions, and Moodle STACK questions for questions requiring more complex mathematical expressions. Feedback was an important component of the design of the questions. The key advantage of feedback is that students understand where they went wrong (embedded feedback), and/or that they receive a general solution approach that will help them to retry the same question. The design and development of questions in the question bank involved the input of all the academics and student partner. The student also coordinated student testing of questions in the question bank with fellow students in order to gain valuable feedback to improve the questions. All images were designed using readily available and easy to use software (PowerPoint) to ensure ease of future updates.

Implementation

Chemical Engineering

With the key aims being to encourage students to keep up with the concepts covered in their lectures, to prepare students for their tutorials, and to have a tool to identify potential knowledge and skill gaps, the question bank was implemented as weekly short (<1 h) summative quizzes worth 1-2% each (Table 1). Each quiz was open book and unmonitored, with students allowed to attempt each quiz multiple times. The participation was high for all seven quizzes (>90% of cohort).

Table 1: Implementation and usage statistics for Chemical Engineering

Implementation	Description	Usage Statistics
Marked Quiz 01	Fluid Properties and Physical Quantities	608 by 209 users (97.7%)
Marked Quiz 02	Rheology of Fluids and Semi-Solids	439 by 207 users (96.7%)
Marked Quiz 03	Fluid Statics	918 by 210 users (98.1%)
Marked Quiz 04	Fluid Dynamics	609 by 204 users (95.3%)
Marked Quiz 05	Fluid Handling – Flow in Pipes	242 by 203 users (94.9%)
Marked Quiz 06	Fluid Handling – Pump and Pumping	1477 by 203 users (94.9%)
Marked Quiz 07	Dimensional Analysis and Similitude	1352 by 208 users (97.2%)
Marked Quiz 08	Differential Analysis of Fluid Motion	685 by 202 users (94.4%)

There were several observations on the impact of the question bank. These related to a significant reduction in support traditionally requested by students, and an increase in the quality and complexity of student queries. Prior to the question bank being implemented, the academic would receive multiple emails from students asking questions around basic concepts covered in the course. The question bank unexpectedly reduced email support to nearly zero. Another observation centred on an increase in the quality and complexity of questions in the online course forum, lectures and tutorials. This signified that the question bank potentially helped students to identify their knowledge and skill gaps. ML noted several gaps and areas for improvement with the question bank. The question bank was noted as being not enough by itself to scaffold students to understand more complex questions, or instil confidence and strategies to tackle the course material. The first iteration of the question bank also had a few errors that frustrated students. A pilot using a third-party question bank was also trialled at the same time within the course; however it was observed that students engaged more with the Moodle question bank than with the third-party question bank.

Civil Engineering

The online question bank was implemented into 20 separate quizzes (Table 2) to allow students to practice questions as often as they want without any marks. The quizzes became available to students in parallel to the lecture topics. All quizzes contained between 10 and 40 questions of varying difficulty to allow students to practice. A separate Moodle Discussion Forum was set up, where students could post questions regarding practice questions, clarify feedback or alert the academic to potential problems with a question (such as missing words or variables, checking of correct answers, etc.). The Forum was managed by a Postdoctoral Teaching Assistant. One valuable lesson learnt during the trial of the question banks was the importance of quickly fixing any issues with quiz questions (which did not always occur) in order to avoid potential student frustration with incorrect questions. Overall, the quiz appeared well received by students and it was a good practice for the two marked online quizzes in the course (i.e. students new to the style and working of quiz questions). At the start of the course there was more participation (>50% of cohort), and this declined throughout the course to less than 20% of the cohort. Initial observation was that there were potentially too many questions in the quizzes, and once the course assessments were completed, students did not attempt the quizzes as often. This is supported by the 100% participation score in the two marked quizzes that took place in Weeks 4 and 7. Once the marked online quizzes were finished, student participation dropped (see drop from Practice Quiz 11 in Table 2). A future idea is to have weekly quizzes with small marks assigned to them to encourage continuous student learning and practicing. Formal student feedback scores revealed positive feedback for the online resources in the course, including the question bank (5.12 agreement and 94.8% satisfaction) and the overall course (4.96 agreement and 93.3% satisfaction).

Table 2: Implementation and usage statistics for Civil Engineering

Implementation	Description	Usage Statistics
Forum	Forum for practice questions	7347 by 263 users (48.7%)
Practice Quiz 01	Dimensions	8352 by 397 users (73.5%)
Practice Quiz 02	Fluid properties - basic understanding	17882 by 343 users (63.5%)
Practice Quiz 03	Fluid properties - numerical	8962 by 259 users (48.0%)
Practice Quiz 04	Hydrostatics - Manometer	16211 by 271 users (50.2%)
Practice Quiz 05	Hydrostatics - Forces submerged bodies	14121 by 257 users (47.6%)
Practice Quiz 06	Hydrostatics - Miscellaneous	3899 by 163 users (30.2%)
Practice Quiz 07	Kinematics of Fluid Motion	2411 by 158 users (29.3%)
Practice Quiz 08	Continuity	5272 by 183 users (33.9%)
Practice Quiz 09	Bernoulli equation - basic examples	4750 by 146 users (27.0%)
Practice Quiz 10	Bernoulli equation - applications	3744 by 119 users (22.0%)
Practice Quiz 11	Momentum equations	4145 by 134 user (24.8%)
Practice Quiz 12	Pipe flow - Basic understanding	2111 by 91 users (16.9%)
Practice Quiz 13	Pipe flow - Friction losses	2552 by 86 users (15.9%)
Practice Quiz 14	Pipe flow - Local losses	2254 by 63 users (11.7%)
Practice Quiz 15	Pipe flow - applications	1426 by 73 users (13.5%)
Practice Quiz 16	Dimensional Analysis - basics	2714 by 80 users (14.8%)
Practice Quiz 17	Dimensional Analysis - applications	1305 by 75 users (13.9%)
Practice Quiz 18	Physical Modelling	1690 by 75 users (13.9%)
Practice Quiz 19	Boundary layer / Friction force	1082 by 83 users (15.4%)
Practice Quiz 20	Drag force	2432 by 98 users (18.1%)
Marked Quiz 1	Topics from Practice Quizzes 01 - 08 (5% of course marks)	21757 by 550 users (100%)
Marked Quiz 2	Topics from Practice Quizzes 09 - 11 (5% of course marks)	22391 by 544 users (100%)

This satisfaction was much higher compared to previous years and was above the school average. One student mentioned in their feedback: “The online Moodle practice quizzes are wonderful and super helpful and I would like to thank you for having it prepared!” Other students were less satisfied, with one student complaining, “The online question bank was overwhelming with the number of questions, and also there were many cases of broken questions etc. which put me off attempting them as it didn't seem efficient and would lead to confusion”. In reality, the number of questions with problems was relatively small. However, the lessons from the feedback included more agility required for the academic to address notified problems, and reducing or chunking the number of questions presented to students.

Mechanical Engineering

The online question bank was implemented into 12 separate sets of practice questions (Table 3) to allow students to practice the questions as often as they wanted without any marks. The questions presented became available to students in parallel to the lecture topics. Each set contained ~6 practice questions on average and were directly relevant to the lecture topic of the week. The degree of difficulty of the questions was designed to be advanced. A discussion forum was also set up on Moodle, so that the students could post questions to seek clarification. The forum was administered by the academic and his demonstrators.

Table 3: Implementation and usage statistics for Mechanical Engineering

Implementation	Description	Usage Statistics
Practice Quiz 01	Introduction, physical properties of fluids, fluids in static equilibrium, pressure measurements, manometer	1799 by 361 users (100%)
Practice Quiz 02	Forces on submerged plane surfaces, buoyancy and stability of floating objects, pressures in accelerating fluid systems	1436 by 356 users (98.6%)
Practice Quiz 03	Lagrangian and Eulerian descriptions of fluid flow, continuity equation, flow visualisation, Euler's equation of motion, steady flow energy equation	1087 by 345 users (95.6%)
Practice Quiz 04	Bernoulli equation, hydraulic and energy grade line, energy transfer and general energy equation	1068 by 337 users (93.3%)
Practice Quiz 05	Mid-Session Test 1	764 by 316 users (87.5%)
Practice Quiz 06	Linear momentum equation, forces caused by deflection of jets, forces on nozzles, linear momentum+Bernoulli/Energy equations	1204 by 340 users (94.2%)
Practice Quiz 07	Dimensional analysis and similarity, introduction to laminar and turbulent flow in ducts, Reynolds number, entrance region	1084 by 333 users (92.2%)
Practice Quiz 08	Laminar and turbulent flow in pipes, analytical solutions, Moody chart and Darcy friction factor	1091 by 324 users (89.8%)
Practice Quiz 09	Mid session test 2 Review	513 by 264 users (73.1%)
Practice Quiz 10	External flow boundary layers, characteristics of laminar, transition and turbulent zones. Drag on immersed bodies, skin friction, form drag, variation of drag coefficient with Reynold's number	761 by 281 users (77.8%)
Practice Quiz 11	Compressor, pump and pipeline characteristics	627 by 273 users (75.6%)
Practice Quiz 12	Turbines, centrifugal and axial flow and velocity diagrams	572 by 271 users (75.1%)
Exam sample	Sample of 2015 exam	958 by 333 users (92.2%)
Exam sample	Sample of 2014 exam	769 by 318 users (88.1%)
Exam sample	Sample of 2013 exam	595 by 264 users (73.1%)

The first implementation of the question bank in 2016 had resulted in very positive responses from the students (end of semester satisfaction: 5.29 out of 6). In the second implementation of the question bank in 2017, face-to-face tutorials were replaced with the online question bank, coupled with feedback forums. This had the added benefit of greatly reducing the room and human resources required to run the course, from 7 tutorial rooms and 7 tutors in 2016 down to 0 tutorial rooms and 2 tutors in 2017). In 2017, the online assignment was also made compulsory and contributed 20% towards the final mark of the course.

A critical reflection on the process

As seen in the previous section, the shared question bank did not constrain the way in which learning design took shape in the different courses. In each course the quizzes were used differently, accommodating both formative and summative assessment as well as providing an effective approach to support assessment and feedback processes. Here is the reflection on the process and outcomes, hinting at future directions.

Chemical Engineering Academic

ML felt that the question bank provided more flexibility and was more customisable than a commercial off-the-shelf question bank package that was trialled co-currently. The academic felt their Moodle question bank prepared their students for the tutorials and enabled tutors to quickly proceed to and focus on more advanced concepts during their tutorials. The academic did however feel that the question bank did not help students with critical thinking and advanced learning; they felt that more scaffolding to support students was required, perhaps in either face-to-face teaching or face-to-face tutorials in order to achieve this. The academic also felt that a standard matrix or benchmark for evaluating outcomes of the project would be useful to quantify the efficiency and cost savings of developing learning resources this way. One question around the question bank relates to the long-term sustainability of these resources, and the need for a university or faculty strategy for when the academic/education developer or student as partner leave the project; that is, how to handle project handover and continued development of resources. The fear is that the resources may become 'orphaned' as the course moves on.

Civil Engineering Academic

SF saw only some of their project expectations being achieved. The student cohort was quite diverse and the question bank was only embraced by some of these students. Once the marked online quizzes were completed (Week 7 of the course), student participation in the practice (unmarked) quizzes dropped. For some students, the practice quizzes were still a great medium to study; however, most students appeared purely motivated by marks in quizzes and other coursework assessments. A key learning experience from the project was that not all students work the same way. For many students, it is all about the marks; however, the academic sees the efficacy in providing practice questions as a scaffold for students who are motivated to learn further. Future adjustments will make use of weekly marked quizzes with a small number of questions to encourage continuous learning.

Mechanical Engineering Academic

SC experienced high usage of his question banks. Mechanical engineering had replaced its fluids face-to-face tutorials with online tutorials for the semester, and the usage patterns indicate that resources such as this are relevant and helpful to students in this context. The flexibility of the question banks enabled students to personalize their learning experiences. Students who needed assistance could still seek help through an online forum, while more advanced students could work through the questions at their own pace.

Student As Partner

Based on the feedback from the academics, students appeared to get a great deal out of the question banks. The use of open-source STACK question type was ideal for a minimum viable product and can be easily integrated with our LMS (Moodle). Having a software developer that has experience in this area would enable the team to overcome some of the challenges with the STACK question type, mainly relating to it being developed for mathematical subjects. As such, there were some challenges in terms of capturing the correct answers with precision, and providing personalised feedback to students based on ranges of incorrect answers. There is scope to have more flexible questions that adapt to student needs and provide personalised feedback. In terms of the question quality, students rapidly commented on minor errors in some of the questions. Whilst the questions did have a review process and testing was undertaken with a small sample of students, an improvement for future projects may be to implement a formal quality management system to better automate tasks such as tracking changes, version control and question testing. This should have the effect of minimising student complaints from errors in questions and avoid students choosing not to attempt the questions due to concerns over receiving incorrect feedback.

Educational Developer

The project was successful in several ways. Firstly, the team achieved their objective of designing, developing and implementing the question bank databases into their courses. The project was a collective response to the academics' instructional awareness, that is, their understanding of their teaching pedagogy and practice and how this could potentially be improved to benefit their students (Fang, 2011). The team did quickly realise that the success of the project hinged on the importance of creating a minimum viable product that met a common need for all team members. This highlighted an area for potential improvement in Moodle, which is currently being explored at the university, where the ability to share and continuously sync question bank categories across multiple courses could be of benefit to future similar teams. Early agreement on the project need, clearly defining the project and agreeing on deliverables meant that the team started developing resources early and kept this momentum up throughout the project. The student partner was a welcome addition to the team and his contribution to the project was invaluable in designing questions, building these into the course and running focus groups for feedback. Overall, the team dynamics were quite unique in that the developer noticed that the team are still collaborating months after completing the project. Examples of this include the team applying for grants together, and recognizing other opportunities to collaborate, for example on a project involving sharing lab resources. The developer attributed this to the key factor of the team having the right mix of personalities, and the same individual inherent motivation to improve their students' learning. It was inspirational for the developer to see the team members, all with distinct personalities and competing interests, come together as colleagues to work on one project, and form a community of practice where they continue to add value to each other's practice.

Conclusion and future direction

As evident from the various team members' reflections, the student feedback in end of semester evaluation, and overall student performance, the main takeaway message is that the integration and collaboration presented to produce a single, shared, portable resource to support student assessment of their knowledge of fluid mechanics was a success. By exposing the reflections on the process, this paper follows the lines of McKenna et al. (2004), making explicit the process for others to observe and learn from. The variety of skills available in the team provides a template to support further integration at faculty level and demonstrates the usefulness of peer support, students' engagement and efficient development. The success of the inter-school collaboration in this project also presents a potential future opportunity for cross-university collaboration in the development of shared resources. Of course, there are several technical improvements that can be made to support further development and sustainability of the resource deployment. Further, more fine-grained research is also underway to explore in more detail student learning and their acquisition of key concepts.

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Through the Looking Glass: Visualising Design Details with Augmented Reality (AR)

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CONTEXT

A consequence of the rapid growth of computation power and ubiquity of consumer mobile devices has been that the use of augmented reality (AR) application as educational tools to enhance the learning experience of students has become feasible (Henrysson, 2007) (Nesloney, 2013). In addition, with increasing number of students, the availability and storage space for physical equipment in hands-on laboratory sessions can be an issue for teaching delivery. We have developed an augmented reality application that can be used on student mobile devices to aid in the teaching of Geometric, Dimensioning and Tolerancing (GD&T) in a laboratory session of a Mechanical Engineering Unit. The application package was developed to help students to bridge the gap between the theoretical understanding of GD&T and how it is applied in the manufacturing design process in the industry.

PURPOSE

The objective of this research is to evaluate the efficacy of an augmented reality application designed to create an active learning experience and demonstrate the significance of GD&T.

APPROACH

A specific GD&T laboratory session will include an additional task utilising the augmented reality application. Feedback from students that participate in the new laboratory session will be recorded and evaluated to determine the impact of augmented reality in connecting their experience with the pre-class learning materials and the learning outcomes. Results will be compared with past student cohort feedback on the non-augmented laboratory session.

RESULTS

The majority students perceived that the additionally included exercise, incorporating the AR application was beneficial in reinforcing their knowledge on geometric tolerances.

CONCLUSIONS

The research study demonstrated the effectiveness of AR as an additional learning tool in providing students the opportunity to develop better understanding and visualisation with a hands-on experience in real-time. Indeed, students find this comparatively more engaging than the conventional teaching methods that involve the measurement of different dimensions of various mechanical parts to quantify manufacturing imperfections.

KEYWORDS

augmented reality, geometric dimensioning and tolerancing, tolerance, metrology

Introduction

The undergraduate Mechanical Engineering unit, MEC3416 Engineering Design II at the University of Monash is designed to introduce students to the design of machine elements, covering the aspects for bearings, shafts, gears, etc. Ultimately, upon successful completion of the unit, students are expected to have a comprehensive understanding on geometric and economic tolerancing as well as to examine the techniques for improving engineering designs based on economic and functional requirements. During the course of the unit, students will be required to participate in a metrology laboratory closing the end of the semester. The briefing sessions and series of online video presentations were given to the students prior to the laboratory session. All things considered, the overall learning outcomes that were designed into the laboratory revolves around the following elements:

1. Describe the role of measurement in the manufacturing design process
2. Measure dimensions of parts to verify manufacturing output on a component level
3. Specify the geometric tolerances required for a functional design

In the laboratory, students are presented with different components, detail drawings with specifications, the metrology tools and corresponding metrology report. The tasks allocated to the students was to first analyse and study the drawings and through observation of the parts, then infer possible functions of the assembly and relationship between the components. Subsequently, with the use of the tools (Vernier caliper, micrometer, etc.) provided, students are to measure the parts and document the measurements in the metrology report template. Thereafter, the students were instructed to determine the passing and failing criteria for the parts with the average readings obtained. At the same time, from the data collected, students then analyse and make the deduction on whether the intended functional operation of the component has met the specifications or else fail. In addition, the students were then expected to reflect and comment on the different parts, this time keeping in mind the passing and failing criteria that was drawn out from the observations earlier.

As an additional component or element for the laboratory, a different approach of incorporating an augmented reality application as an additional learning tool was considered. This added aspect was explored as a consequence of new advances in augmented reality content creation as well as the ubiquity of student mobile devices, in which using such application to enhance the learning experience of students has become greatly possible and achievable. Interestingly, most augmented reality application being developed are compatible to increasing number of mobile devices due to the rapid growth in computational power and the significant decrease in power consumption (Henrysson, 2007). Taking advantage of these, augmented reality can be introduced to the students and even be used on their mobile devices to aid in the teaching of a particular material content. On top of that, the idea of the inclusion of augmented reality in learning space can also resolve the issues of having limited availability and storage capacity for equipment in hands-on laboratory experiments too.

Augmented reality (AR)

Augmented reality (AR) is a mixture of a direct and indirect view of the physical, real-world environment, a technology that superimposes computer-generated elements over a user's view of the environment, which can be as simple as through a display of a camera. It is a space; a vision where digital domains can be blended with the impression of the physical world. Augmented reality enhances individual's perception of reality, whilst virtual reality replaces the entire real world with a simulated virtual environment (Henrysson, 2007). Thus, augmented reality creates a composite mixture of reality. This can be best described with the Milgram's Reality-Virtuality Continuum as shown below.

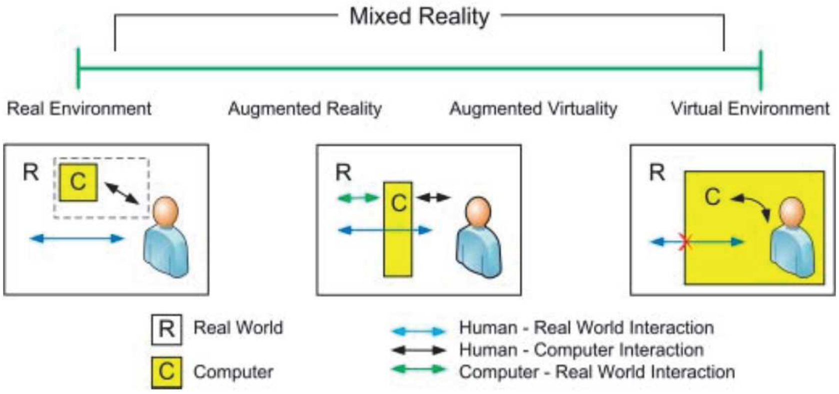

Figure 1: Milgram's Reality-Virtuality Continuum (Henrysson, 2007)

The continuum spans from real-world environment to virtual environment at both extreme ends, where in between lies the mixture of reality. With reference to the figure above, augmented reality superimposes both the domains of human-real world interaction and computer-real world interaction, where this eliminates the need for switching of focus between domains (Henrysson, 2007). As augmented reality has the characteristics of combining both real and virtual elements, information such as the surrounding environment of the users can become more interactive and manipulable in real-time.

Motivation

Having learners diving into the augmented space where they can have two-way interactions with virtual objects in the digital domain and the physical real-world environment, is rising as one of the prominent approaches in creating unique educational settings. The means of incorporating augmented reality as part of a teaching and learning tool has created much interest in the education field with the intention to enhance and redefine learning experience of the learners (Kesim & Ozarslan, 2012) (Wang, 2012). It is also said that augmented reality is aligned with the constructivist notions of education, in which promotes self-directed learning through interactions with the real and virtual environment (Wang, 2012).

In fact, the augmented reality application in this context will be focusing on how AR as an additional learning tool can be a supplement to the learnings of the students, rather than replacing the conventional method of implementing two-dimensional medium in education.

The potential of augmented reality in education is also justified with the ability to provide an adequate level of realism, in which individuals are not disconnected entirely from the real environment (Kesim & Ozarslan, 2012). To emphasise on the statement above, augmented reality can be adopted as an additional learning platform for students to visualise things as part of the learning process more effectively, leading to the creation of a more intuitive learning experience which can boost their level of understanding. A structured interaction with the moderate dynamic representation of information is known to be able to improve learning significantly as articulated in research conducted in the past (Bodemer, Ploetzner, Feuerlein & Spada, 2004).

This study analyses whether the nature of augmented reality is capable of complementing the overall learning experience of the students in terms of better visualisation, and provide a context for incorporating augmented reality application in the curriculum of studies.

Methodology

To analyse the effectiveness of augmented reality in enhancing the learning experience by creating a mixed reality environment where users can interact and manipulate the surrounding superimposed elements, an augmented reality application prototype was developed. The application package developed was with the intention of providing a platform for students to visualise how different tolerances could place an effect on the manufacturing output on a component level and the subsequent functional operation of a part. Therefore, the primary motive is to complement the existing metrology laboratory in reinforcing the understanding of Geometric, Dimensioning, and Tolerancing.

Software Development Tools

A list of tools and platforms used to develop the augmented reality application are provided below, followed by a brief description of each.

1. Vuforia Augmented Reality Software Development Kit (SDK)
2. Unity3D Game Engine
3. MonoDevelop (Xamarin Studio)
4. Blender

Vuforia is a fundamental software element that was used to enable the building block of the augmented reality application. This software is utilised to provide tracking and recognition capabilities on different pre-defined targets by employing computer vision technology. In the case of the developed application, a planar image tracking along with the 3D object (point-cloud based) tracking were implemented to superimpose virtual components on the physical world environment in real-time.

Unity3D is a game engine that was used for the functions to create, edit and integrate data and code onto the recognised target markers in the real-world space. Unity allows the overlaying of different digitalised components with relative to the target in the physical environment. The tools offered by the software package such as the user interface blocks were also exploited to create a more intuitive and interactive application, where users will be able to manipulate the augmented objects in real-world space.

MonoDevelop which is an inbuilt application of Unity, which is an open source integrated development environment, which enables advanced C# scripting for more complex high-level applications. It was used to compile cross-platform application by the compiler of Unity. Fundamentally, MonoDevelop was used extensively to provide corresponding interactions and feedbacks between the user and the augmented components in the scene.

Blender is an open-source 3D computer graphics software, which was used to create and render objects and components with higher complexity in shapes to create a more realistic 3D augmented reality application. For instance, 3D modeling, texturing and more features were used in creating the different assembly parts to be generated for the application.

The above tools and platforms were chosen in developing the augmented reality application is because they have the common features in offering a cross-platform development engine, where the built application package is compatible with many different devices and operating system. Essentially, the software packages are also free for development purposes with a wide range of inbuilt functionalities and application program interfaces (APIs). Not to mention, they also provide great documentation and community to aid new developers.

Approach

A total of four students who previously participated in the laboratory session were invited to participate in a survey evaluation and application usability test to evaluate the augmented reality application that was designed to enhance the learning of the concepts in Geometric, Dimensioning and Tolerancing. The survey was intentionally simple, designed to investigate if the perceptions and understanding of tolerances on the manufactured output were amplified with the additional element of having augmented reality as part of their activity. The primary questions asked and focused in the survey questionnaire was whether the students understand the following aspects before and after the exercise:

1. The context of tolerance in parts manufacturing perspective
2. Effects of tolerance on the operational function of the product

These were both evaluated first at the pre-activity of the session and towards the end of the activity to review the effectiveness of augmented reality in bridging the gap between theoretical and practical understanding through constructive visualisation of the material presented. Moreover, a background video of the testing was also recorded for usability testing to evaluate the AR application developed, thus, provides a direct input on the tool's capacity to meet its intended purpose.

In essence, the activity for the survey evaluation for the augmented reality application was carried out at 3 different stages, comprising of understanding assembly drawings, generating the augmented part with different tolerance set, and finally analysing the functional operation of the assembly with the augmented part interfaced with the physical 3D-printed base.

The participating students were first briefed with instructions for the testing at the start of the session, which was then followed with a pre-activity questionnaire. A 3D-printed base with feature markers was then provided to the students with the assembly drawing, along with the specification of the clamp to be generated in the augmented space. Each student was also provided with a tablet with the developed application package installed beforehand. Consequently, the overall setup of the testing includes an Android device, assembly drawings for both 3D-printed base and the clamp to be generated, a target marker for the overlaying and positioning of augmented clamp generated, as well as the 3D-printed base with feature markers attached shown as followed.

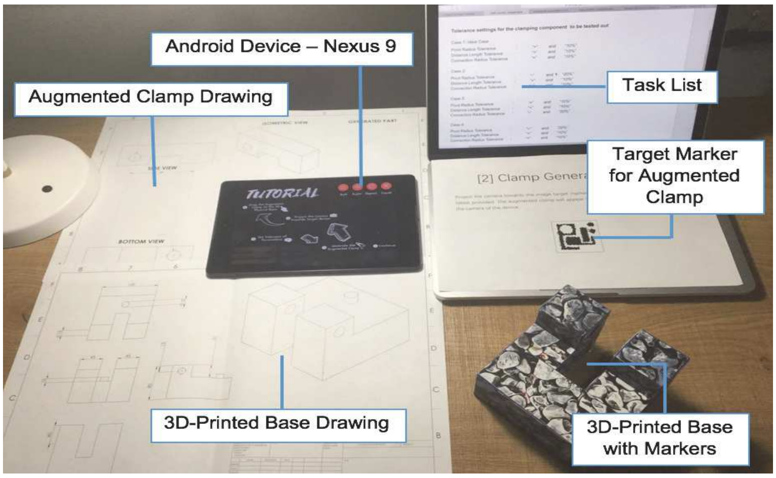

Figure 2: Application testing activity setup

Each student was then given 15 minutes to complete a series of tasks with the augmented application to examine their level of understanding on the effects of geometric tolerance. As a result, their level of understanding can be reflected through their deduction and explanation made on the end functional operation of the assembly.

The procedure of the application testing is summarised in the flowchart as shown below in Figure 5. Stage 1 of the activity involves the student analysing the assembly drawings and understanding the intended functional operation of the end assembly to be constructed. For instance, this includes the required clearance fit for the generated clamp to be interfaced with the physical 3D-printed base and their corresponding functional expectations.

Moving on, students were recommended to follow the tutorial instructions that were embedded in the application for the following stages. In the following stage 2 and 3, students were required to evaluate the effects six different unique cases of tolerance settings (extreme cases), where the corresponding output obtained was studied. The set of tolerance settings for the analysis was provided and upon inputting the tolerance, students can then generate the augmented clamp on the target marker in the scene with respect to the corresponding set parameters. Students then able to look at a different view of angle of the generated augmented clamp in the scene by projecting the tablet's camera onto the image-based tracking marker. Once students are satisfied with the part generated, they can then interface both the augmented clamp and the 3D-printed base together in the real-world space by dragging the corresponding part to the physical base provided. At the instance when both the augmented component in the digital domain and the physical base in real-world space collide, the clamp would then be clicked onto the base, creating an assembly as shown in Figure 3.

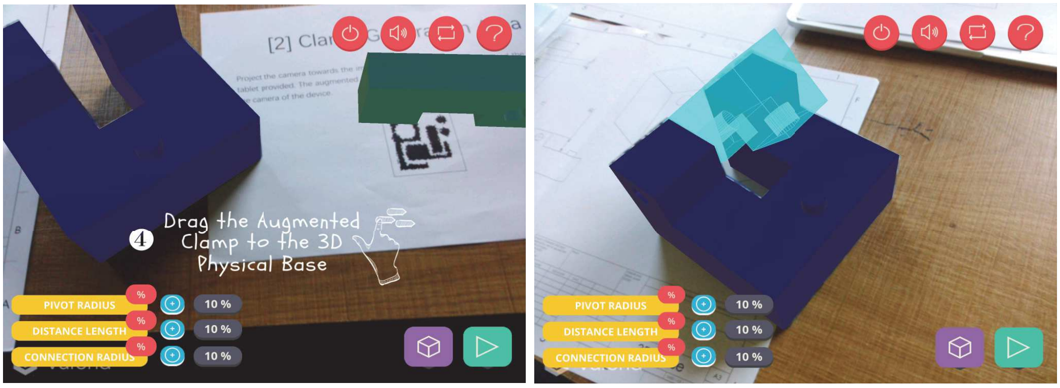

Figure 3: Generated augmented clamp and interfaced assembly

The interfaced clamp would then change from a solid texture colour to wireframe to provide better visual views of the clamp.

In stage 3 of the exercise, students were directed to the next scene where the interactions of users and the augmented elements come into place. Likewise, the students can then interact with the augmented clamp generated and manipulate them with the user interface that was designed. For example, this includes rotating the clamp around the pivot of the physical base to translating the parts if the connection was loose. Through the observations and interactions, students are then required to examine the effects of the tolerance set previously in generating the clamp on the relative clamping mechanism.

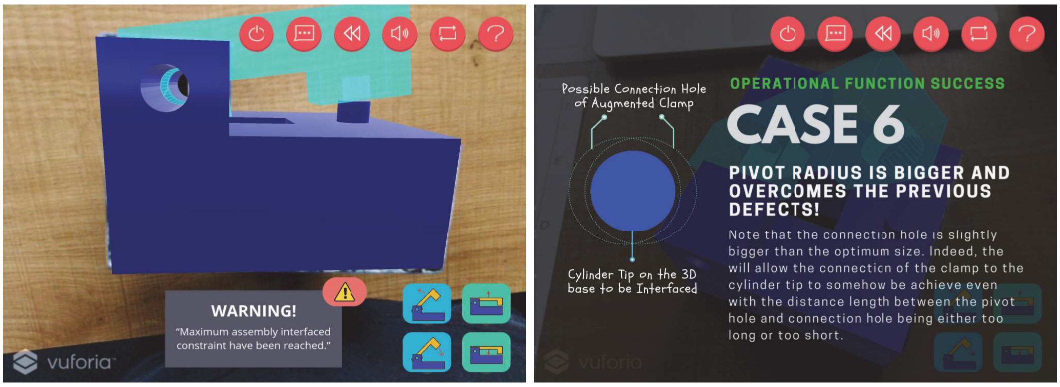

Figure 4: Built-in interaction feedbacks and analysis to aid learning

More interestingly, with augmented reality, students can instantly observe the assembled part at different angles. Furthermore, feedbacks were also received based on their interaction with the assembly, which can be in the form of vibrations when the part's movement reaches the boundary limit of the interface to distinctive alert messages to aid in their understanding as illustrated in Figure 4. For all intents and purposes, the students are expected to be able to verify their understanding of the effects of tolerance setting that was allocated for the clamp generated towards the functional operation of the end assembly. The steps discussed above are then repeated to explore the other possible cases and then concluded with the post-activity survey questionnaire. A short interview was also conducted with the participants to get some valuable feedback on the features they find helpful and elements to be improved or amended to further revise the application package developed.

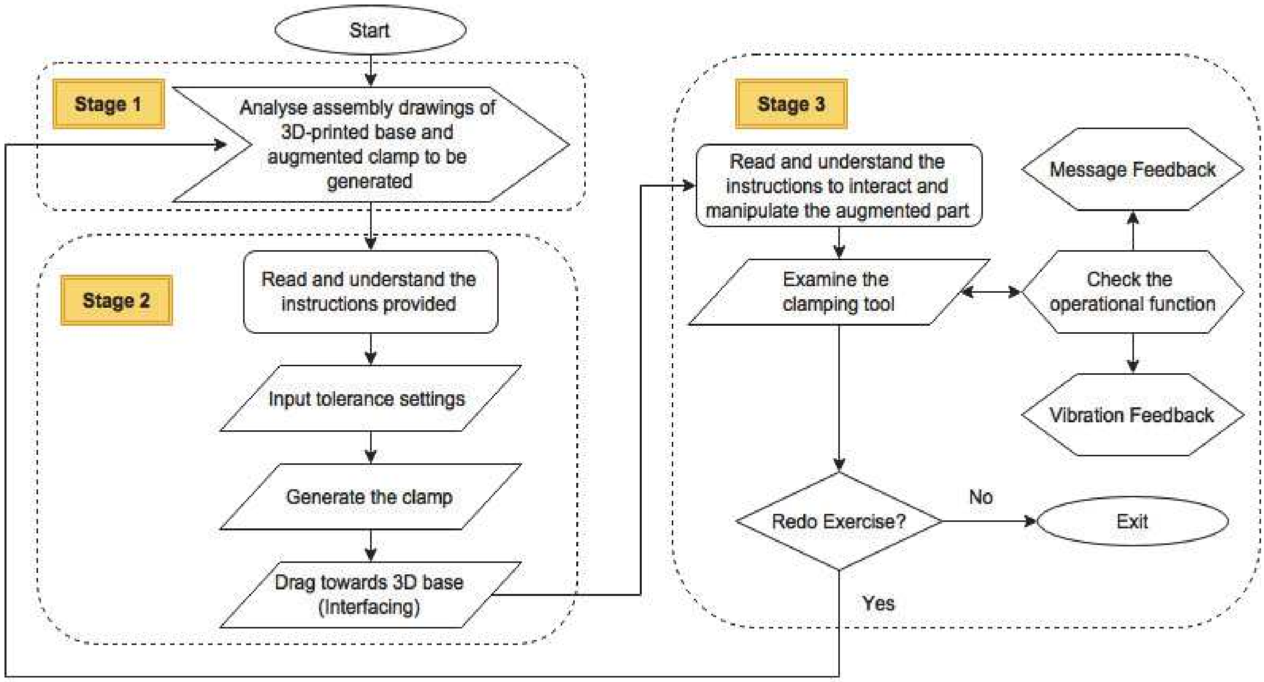

Figure 5: Overall application testing flow

Results

Understanding of tolerance

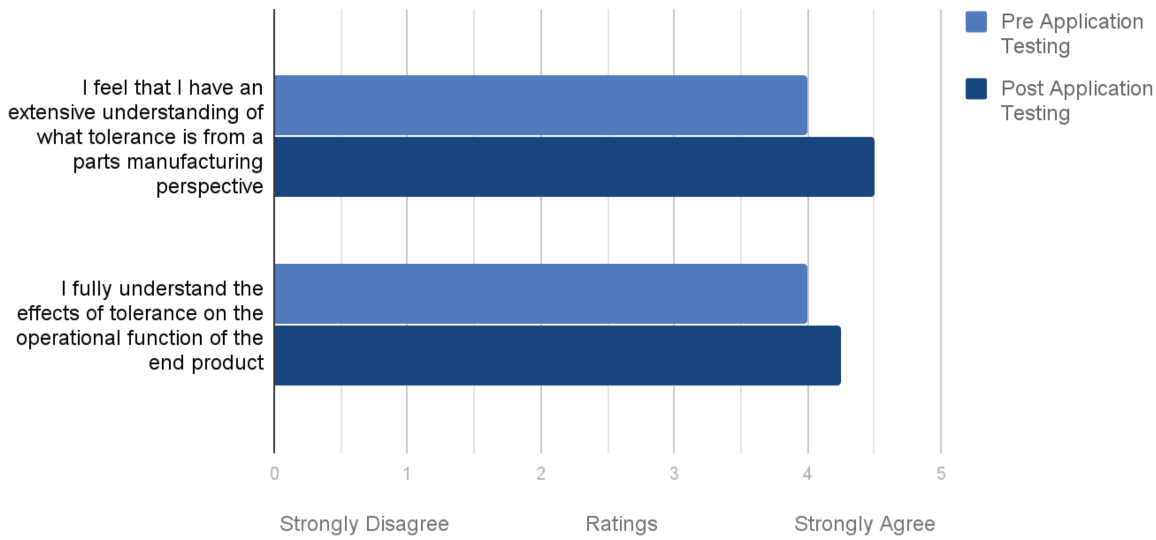

Figure 6: Relative feedback on the understanding of tolerance

The relative feedbacks of the initial part of the survey is then tabulated as shown in the Figure 6 above. Overall, the students who participated in the survey evaluation could develop a better understanding on what tolerance is from a part manufacturing perspective after using the augmented reality application package, where there is an increase of the average rating of 0.5 from 4.0. On the other hand, students find themselves having a greater viewpoint and perspective on the effects of difference set of tolerance for the generated part towards the operational function of the end assembly after the corresponding interfacing was carried out. As a result, there was a slight increase in the overall ratings, which reflects that there is a considerably good amount of added value to the learning experience of an individual with the use of external learning tools such as augmented reality.

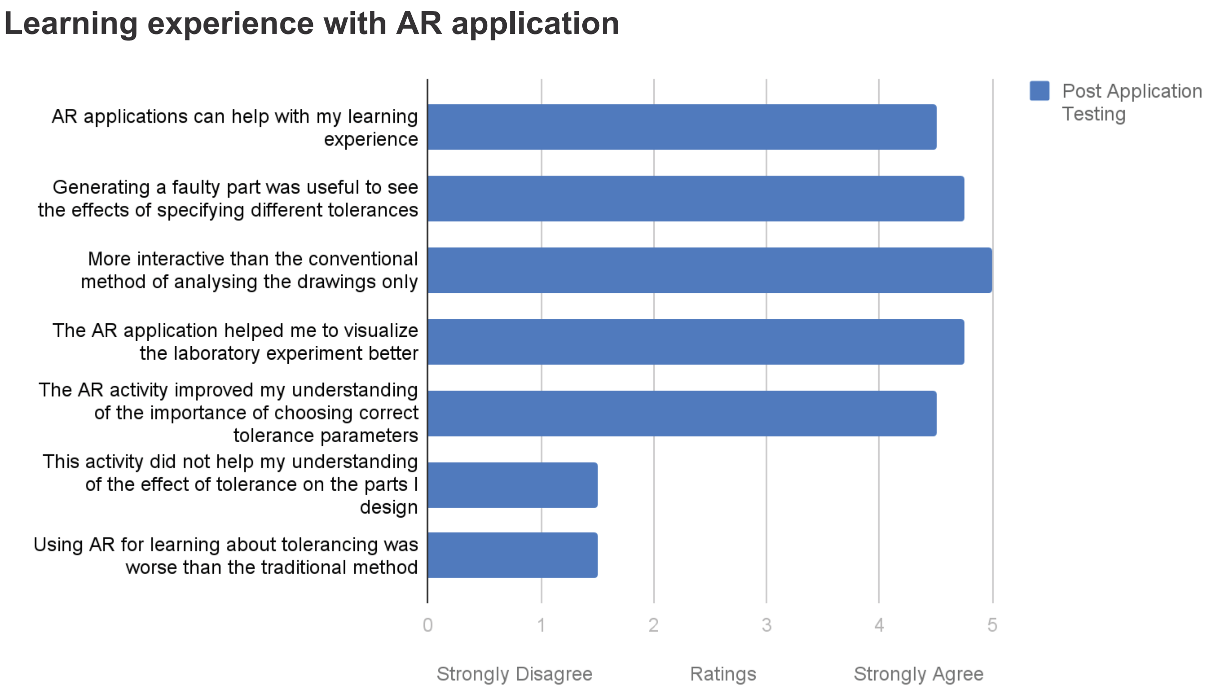

Figure 7: Feedback on the learning experience

On average, participating students believed and acknowledged that the additional assistance of having the developed augmented reality application creates a more intuitive environment for better learning experience. Indeed, the result turned out to be at the best rating possible of 5.0, where students strongly agree that this approach of learning was more interactive than the conventional method of just analysing the assembly drawings. Figure 7 also shows the use of additional tools such as augmented reality can promote better visualisation of the laboratory experiment, especially with the ability to generate a faulty part on the instance and observe the subsequent effects on the assembly. Majority of participating students also considered that the AR activity has improved their understanding of the importance of choosing the correct tolerance parameters, to produce parts that are within the usability criteria. There was also a positive outcome from the data collected, in which past students disagreed with the statement that the additional augmented reality application prepared for the activity didn't help them in learning more effectively with a rating of 1.5.

User experience with the AR application

Further analysis showed that students have a constructive and interactive experience in using the augmented reality application during the activity with a total average rating of 5.0 as illustrated in Figure 8. Some students participated in the activity found it slightly complicated to get started, however, most of them got used to it over time. In brief, students find that the additional activity of having augmented reality incorporated into the laboratory would have been helpful for them when undertaking the laboratory session in the past.

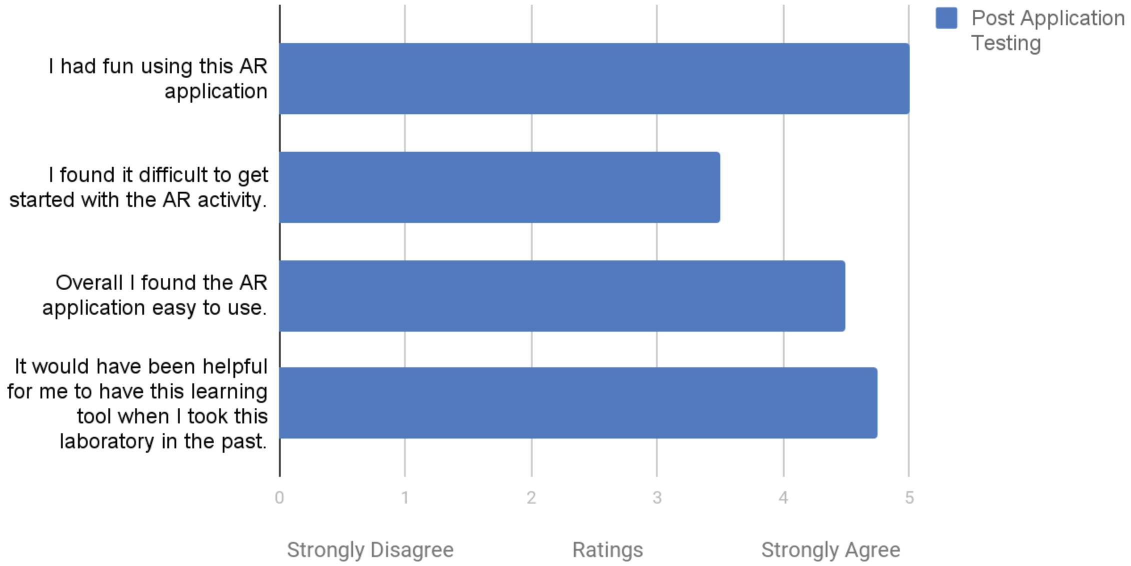

Figure 8: Feedback on user experience

Usability Test

From Figure 9, a positive correlation can be observed between the transition of each cases that was carried out by the students, where the time taken for students to complete a set of task is reducing as they get used to the augmented reality application. This clearly indicates and justifies the usability of the application developed as users were able to meet the expectations at the given timeframe. As for the scenario where students encounter any difficulties or experience any form of confusion, the longest time taken to overcome the issue was below a minute. Hence, the application is usable and intuitive to some extent as there were minimal issues that were experienced by the users.

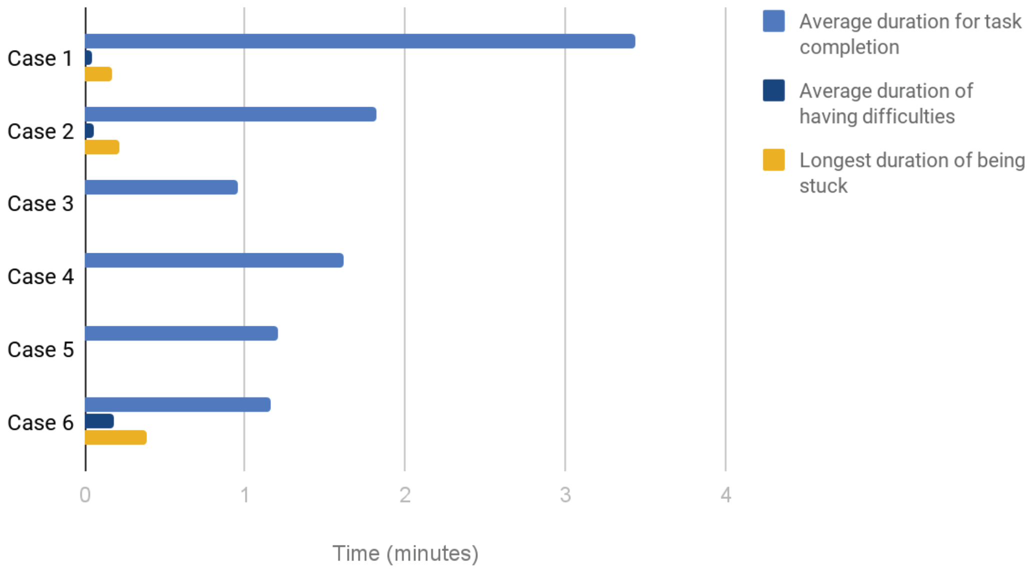

Figure 9: Data collected from recording for usability test

Discussion

As all students participated in the survey evaluation activity completed the tasks allocated with the allocated time, our results obtained met the expectation in students improving the understanding of Geometric, Dimensioning and Tolerancing concept. Also, the augmented application was observed to have created a more interactive and engaging learning experience, as students were interacting with the digitalised virtual object and the physical base at the different point of views. The fact that students were able to make the correct deductions on the effects of the tolerance set on the end functional operation of the assembly strongly linked to totality that augmented reality can provide in the learning phases.

Other comments worth noting from the students were that having the additional element of augmented application would be a really useful tool to help them understand any topics being taught in a more captivating approach. Besides, from the feedbacks collected, students find this method of learning fun and efficient in terms of quality and speed of teaching. The students participated in the activity also appreciates the value of augmented reality in having the ability to provide them different dimensional viewpoints of a piece of information for better visualisation.

On the other hand, a selection of students found the tutorial instructions incorporated into the application interface slightly confusing at the start, but the overall feedback was easy to use after they get used to the functions. At times, some students couldn't see the parts clearly due to the factor that the colour combination of augmented part and the physical object after the overlaying was not clearly distinguishable. Another constructive feedback was that the dragging and dropping of the generated part onto the base model in the real-world space was a bit glitchy and maybe unnecessary as well.

Next, from the usability test conducted simultaneously, some potential issues were highlighted such as the developed augmented reality application can be glitchy at times, in which the camera lose track of the augmented part before the interfacing phase. Despite that, the application was able to be reset with the user interface button embedded and was fully functional after that. It may be due to the factor of bad lighting in the testing room, where a marker of bigger size and a comparable larger number of feature points on target markers could potentially fix the glitches. Nonetheless, the application developed as a whole in terms of its likelihood of usage and repeatability was satisfactory.

Additionally, as for the future work on the augmented reality application, would be to explore more into its capabilities and potential in the creation of a more interactive learning environment. Similarly, a more compact and simple tutorial instruction would be integrated into the application without compromising the relevant details, to heighten the level of interaction between the user and the digitalised components.

Conclusion

While the AR application is designed to help investigate the effectiveness of the additional tool in providing an interactive learning experience, the exercise conducted showed great potential and viability of augmented reality in the education sector. Results of the activity carried out also indicate that augmented reality as a supplementary tool can be highly effective in providing learners a platform for better visualisation in bridging the gap between the theoretical understanding of Geometric, Dimensioning and Tolerancing and the practical application and effects in the manufacturing design process.

Augmented reality is a tool where students can test and examine their level of understanding by applying the appropriate interaction to the superimposed digitalised component in real-time. The feedback in terms of visual can be provided at the instance, which is supported by the fact that there is no cost involved in making mistakes and errors. Thus, it creates opportunities for more practical and diverse learning. With AR, the definition and scope of learning experience can be expanded and redefined into a whole new level.

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A systematic approach to teaching and learning development in engineering

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Context

Over the last three years, as academic course designers in the Learning Support Team, we have supported academic staff in the School of Engineering at Deakin University, to develop and implement courses and units using the Project-Oriented Design Based Learning (PODBL) approach. During this time, Deakin University also embarked on Course Enhancement, which was a major curriculum renewal process. Together, these strategic objectives aimed to improve student experiences and learning outcomes, thereby preparing them for the jobs and skills of the future. The school's initiative combined with the University's intervention, provided us the opportunity to work closely with academics. Our aim was to build academic capacity for developing teaching, learning and assessment activities, that enable our students to evidence learning outcome achievement.

Purpose

Drawing from examples around teamwork skill assessment, this paper describes the systematic approach taken to support pedagogical change in academic practice, from a teacher-centred approach to a student-centred approach. We emphasise the need to support academics from the design stage through to delivery of teaching, learning and assessment of their units.

Approach

Shifting the academic's thinking about their pedagogical approach, required review and revision of teaching, learning and assessment practices in many units. We interviewed academics and then workshopped ideas for teaching and assessing specific unit and graduate learning outcomes. Following the interview, volunteering academic staff members were recruited to implement changes to their units, in alignment with the course-level thinking. These academic staff were provided with personal one-on-one support to integrate graduate learning outcomes into their unit and assessment design. Our support then continued beyond the initial design phase to include practical advice during the teaching and assessing delivery phases, and ended with unit performance reflection and consolidation.

Results and Conclusion

Shifting to learner-centred teaching and learning activities was quite confronting and challenging for most. A recurring theme was the reference to "soft skills", with the implication that these skills were not as important as the "hard skills" of discipline-specific knowledge. Additional concerns included lack of time, and the stress associated with teaching and assessing skills outside their 'comfort zone'. By taking this systematic approach, we were able to foster positive and trusted relationships with early adopter academic staff. This resulted in measureable growth and development in their teaching and learning skills. These academics in turn became role models for change within their course teams.

Keywords

Curriculum change, pedagogical change, teaching and learning support.

Introduction

In recent years, there has been an increasing national focus on higher education institutions to assure graduate capabilities. This is done through ensuring the validity, reliability and comparability of learning outcomes in a degree course, and student achievement of those learning outcomes at an appropriate standard (Oliver, 2015). In Australia, universities have implemented an agreed set of Graduate Learning Outcomes, irrespective of the discipline or level of study, which are translated into course-level, unit-level and assessment-level outcomes. During their degree course, and through a number of assessment opportunities, students develop evidence and demonstrate success towards achievement of graduate capabilities at an appropriate standard in order to obtain their degree.

For engineering, graduate capability (competency) standards are set and monitored by Engineers Australia. King (2008) in his review of engineering education, identified six key recommendations that boldly called for changing the status quo of engineering education for the 21st century.

1. Raise the public perception of engineering.
2. Refine definition statements of engineering occupations to develop, promote and support all members of the engineering professional team, in order to enable collaborative work in the sector.
3. Develop best-practice engineering education, promote student learning and deliver intended graduate outcomes.
4. Enhance staff capacity and material resources to enable the delivery of an aligned and integrated engineering curriculum.
5. Improve the authenticity of engineering education by engaging in partnerships with the industry to enhance graduate employability skills.
6. Address shortages in the engineering workforce by increasing diversity in the workplace and by offering a range of engineering education programs matched with industry trends.

At the same time, engineering education must also deal with other pressures that have brought many universities to rethink their educational strategies. These pressures include, but are not limited to:

- Rapid increase in competition from universities within Australia and beyond, for example through open courses.
- A significant decrease in funding from the federal government.
- Greater scrutiny on change and its effectiveness through performance measures.
- Maintaining student satisfaction with their educational experiences.

Deakin University's School of Engineering responded to these challenges through the development of the Project Orientated Design Based Learning (PODBL) methodology for training future engineers. The PODBL methodology uses Design Based Learning (DBL) as its core. DBL integrates problem solving and collaborative teamwork with hands-on activities and creative design techniques that requires students to make logical connections, identify cause and effect, draw analogies, and think critically at the highest level. The change idea associated with the implementation of PODBL was to shift from the current content-driven approach to a learner-centred approach to teaching and learning (Agouridas, 2007; Chandrasekaran, Stojcevski, Littlefair, & Joordens, 2013).

Around the same time, Deakin University embarked on an intervention called "Course Enhancement". This project was underpinned by Deakin's promise to students, and was designed to improve teaching and learning at an institutional level. A key outcome of this project was the design and delivery of courses that supported student development and achievement of transferable skills referred as Deakin Graduate Learning Outcomes (GLO). Table 1 below illustrates Deakin GLOs. Students develop these outcomes throughout their degree course in the context of a discipline, for application either in the discipline or outside of the discipline in jobs and skills of the future (Deakin University's Strategic Plan).

Table 1: Deakin University's Graduate Learning Outcomes

GLO1	Discipline knowledge and capabilities:	appropriate to the level of study related to a discipline or profession
GLO2	Communication:	using oral, written and interpersonal communication to inform, motivate and effect change
GLO3	Digital literacy:	using technologies to find, use and disseminate information
GLO4	Critical thinking:	evaluating information using critical and analytical thinking and judgment
GLO5	Problem solving:	creating solutions to authentic (real world and ill-defined) problems
GLO6	Self-management:	working and learning independently, and taking responsibility for personal actions
GLO7	Teamwork:	working and learning with others from different disciplines and backgrounds
GLO8	Global citizenship:	engaging ethically and productively in the professional context and with diverse communities and cultures in a global context

Change ideas, such as these, are intended to cause significant broad scale disruption for improving current practice. Scott, Coates and Anderson (2008) quoted Fullan's (1982) seminal work on effective change management in higher education.

> *"Good ideas with no ideas on how to implement them are wasted ideas" and "Change doesn't just happen but must be led, and deftly".*

He implied that it is vital that leaders, at all levels strategically plan for implementing change. In this paper, we present a systematic approach to supporting teaching and learning development in the School of Engineering at Deakin University. While our support involved many areas of curriculum design and development, here we focus on our plan and the strategies we used to advance the capacity of academics to integrate teaching, learning and assessment of teamwork skills.

Learning and Teaching Support

Learning and teaching support at Deakin University is both centralised and distributed. It follows the hub and spokes model (Gosling, 2009), where staff members employed by Learning Futures, provide planned support for teaching and learning development in collaboration with Faculty teaching support staff who provide day-to-day operational support. Within the Faculty of Science, Engineering and Built Environment, learning and teaching support staff operate as the Learning Support Team. This team consists of academic and professional staff members that support various functions from course and unit design, to learning resource production, and evaluation of teaching and learning performance.

Our job, as academic staff in the Learning Support Team, is to influence academic action through the provision of resources, tools and professional development, to enrich student learning and experience. This way, the academics become our learners, and our role as change agents is to support and facilitate their scholarship in Teaching and Learning. We provide personalised support for academics at their point of need to cater for considerable diversity in their pedagogical knowledge and preparedness to teach in higher education. Our approach presented here, is extracted from both the support we provided for Course Enhancement project activities, as well as the School's initiative to redesign engineering courses and units for delivery using the PODBL approach.

Facilitating Self-review and Problem Identification

In the PODBL approach, while learning activities in many PODBL units required students to complete tasks as part of a team, we found that strategies for teaching and assessment of teamwork skills were not identified or agreed upon for implementation across the course. We informally interviewed the Course Directors and Unit Chairs to understand the reasons for this gap.

A recurring theme was the reference to teamwork as a ‘soft skill’, with the implication that it was not as important as the ‘hard skills’ related to a specific discipline. Several academics also identified that they were not in the best position to assess teamwork, as the meetings and development stages of projects, often occurred external to the classroom. Some assumed that students spontaneously develop teamwork skills when provided the opportunity to work together in groups. Many academics believed that group work and teamwork were one and the same, and used the terms interchangeably.

Our analysis of the assessment tasks revealed that student marks associated with the completion of a team task, was based on the product (design, prototype, model) and not the team process. Academic staff mentioned that they were often questioned by students regarding the equal distribution of marks for production of a product. Some academics responded to that by requiring students to complete a short questionnaire to measure individual contribution and thereby adjusting a student’s final result. These academics observed that this self- and peer-assessment process was often done in hard copy, was difficult and time consuming.

Formulating Responsive Support

To address the issues identified during the self-review, we devised an action plan to:

1. change the academic mind-set of teamwork as a ‘soft skill’ to a vital ‘transferable skill’ that employers seek in university graduates.
2. enable academics to easily and confidently teach and assess teamwork skills using an online tool.
3. build the pedagogical confidence of our academics in the teaching and assessing of teamwork through professional development.

Changing academic mind-set

During our work with academics in enabling their redesign of the engineering curriculum, it became clear that there was a need to promote graduate learning outcomes through teaching, learning and assessment practice. We used a consistent language and encouraged academics to use the same language with students to enable their understanding of graduate learning outcomes. When reviewing assessment and learning design, we challenged academics’ reference to soft (non-discipline) and hard (discipline) skills, in order to improve the integration of transferable skills into the curriculum. We provided key reference material, such as purpose made bookmarks, to develop their vocabulary and definition of these learning outcomes and their alignment with employability skills.

Providing tools for teaching and assessment practice

Working with the central Learning Futures staff, we made an online tool (SparkPlus) available for trial (Willey & Gardner, 2009). Through self- and peer-assessment of student contribution and performance, this tool allowed the calibration of an individual mark from a team task much easier than extrapolating that from hard copy questionnaires. However, during the trial, it became clear that providing a tool and a set of 'how to' instructions was not enough to encourage participation. The lack of 'buy-in' from academic staff to use the SparkPlus tool raised significant questions regarding how to best support teamwork skill assessment.

Although academics wanted to use the tool, they lacked the time to learn about the tool and lacked the confidence to implement the tool on their own. They were also unsure about setting expectations for the level at which teamwork skills should be demonstrated within a unit, and how to teach and assess teamwork skills rather than assessing group work. The change we expected from academics was beyond their preparedness and therefore beyond their comfort zone. This oversight provided the impetus for the development of a strategy to provide professional development.

Professional development

Our academics have significant expertise in their respective engineering disciplines, and knew how to teach those disciplines. However, enabling student development of transferable skills essentially adds to the academic's required subject matter knowledge. We had assumed that academics had the ability to teach and assess a range of transferable skills as core curriculum. As their struggle to integrate transferable skills as learning outcomes became apparent in the interviews, we provided personalised professional development to extend their pedagogical knowledge.

Implementing Systematic Support

Initially, our work was focussed on supporting the academic staff to construct learning outcomes at course level. This was then translated to unit level and assessment level in alignment with the body of knowledge embedded within the unit and the assessment task. This required academics to articulate the intent of the unit that they are responsible for, in relation to other units in the course (Biggs & Tang, 2011).

Our experience in supporting the School of Engineering through this major pedagogical change, confirmed our understanding that all academics aspire to be successful teachers. However, we observed qualitative differences in terms of their experience and developmental needs. Åkerlind (2003, p. 380) categorised growth and development in terms of:

- Teacher's comfort with teaching, in terms of feeling more confident as a teacher or teaching becoming less effortful;
- The teacher's knowledge and skills, in terms of expanding content knowledge and teaching materials, and/or expanding repertoire of teaching strategies;
- Learning outcomes for students, in terms of improving students' learning and development.

Although this research explored structural differences between categories, it stopped short of exploring teacher's comfort with extending learning outcomes beyond the discipline, to integrate transferable skills within the core curriculum. By exploring the ways in which the teacher's understanding and comfort combines with their skills and confidence, we found it necessary to provide dedicated support for teaching and assessing specific transferable skills, for example teamwork skills.

By targeting ten ‘early adopters’, we were able to focus our limited resources to support those academics who were willing to change (Wilson & Stacey, 2004). Our position has been to be supportive rather than punitive. A consequence of this approach is that the change implementation can take time. However, the benefits of this approach, from our perspective, outweighs the stress that rapid and unplanned change can cause.

Our plan has been to utilise the skills of the early adopters for peer-coaching and mentoring, which not only celebrates their work, but also promotes scholarship of teaching and learning (Harris, Farrell, Bell, Devlin, & James, 2008). During the process of change implementation, we were able to influence the formation of trusted collegial relationships within and beyond the disciplinary boundaries. The ten early adopters, essentially promoted the value of the support that we provided to other academics in the School. Validation from the School for unit and assessment redesign work, together with the visible growth of early adopters in teaching and assessing teamwork skills, encouraged other academics to approach us for support.

Based on the premise that we are all learners in a changing environment, building the pedagogical confidence of academics was vital to enable change implementation. As our teaching academics were required to apply the change at the student level, support for each individual at their point of need was a priority. In this change situation, we applied a systematic approach to ensure clarity about the change and were strategic in the use of resourcing pedagogical support for implementation of the change through the support we provided.

Simply put, our identification of three significant challenges, as we formulated a responsive support, helped prioritise support strategies for facilitating and managing the implementation of curriculum change to teach and assess teamwork skills. We commenced this process by providing clarity around what change was needed and why, and what it takes to implement that change. Equally important was to set priorities for ourselves within the Learning Support Team. A summary of our implementation strategy for teaching, learning and assessment of teamwork skills integrated through the core engineering curriculum is illustrated in Table 2.

Table 2: Summary of our systematic support strategy

Strategy	Description
Define the change	The PODBL curriculum is underpinned by teamwork, and students are required learn and achieve project outcomes collaboratively, while demonstrating their own success towards intended learning outcomes. Upon graduation, students should demonstrate teamwork skills in professional situations. Academic practice needed to change in order to integrate teaching, learning and assessment of teamwork skills in the core curriculum.
Justify the change	Teamwork skills are highly valued by employers of engineering graduates. Our initial review of engineering courses identified limited teaching and assessment of teamwork skills. For students to be successful learners in PODBL, teamwork skills needed to be taught, practiced and assessed explicitly.
Establish the timeline	Curriculum change for teaching and assessment of teamwork skills needed to coincide with the progressive implementation of PODBL methodology, as well as other timelines set by the University for handbook publications for the following year.
Identify stakeholders and their responsibilities	As members of the Learning Support team, we took directions from the Faculty into order to support the requirements of the following stakeholders, while respecting their responsibilities and expertise.

	Unit chairs were required to redesign the unit and assessment tasks, ensure alignment of unit learning outcomes with GLOs, and communicate to students how and why teamwork skills were taught and assessed. **Course Directors** were required to facilitate discussions that identified specific units for scaffolding teamwork skills, and negotiate with unit chairs the timeline for implementation. **The School** was required to quality assure that alignment statements were articulated using a student-centred language within unit and assessment information documents. **The Faculty** was required to provide operational support strategies to help the Faculty and the School to satisfy the University's overall goals and vision. **Deakin Learning Futures** was required to facilitate the assessment of teamwork skills in all courses. **The University** was required to fulfil their learning promise to students "to provide a brilliant education that empowers them for the jobs and skills of the future".
Identify challenges and potential solutions	**Valuing teamwork skills** – Building academic confidence in teaching, learning and assessment of teamwork skills. **Meeting deadlines for curriculum change** – Supporting timely redesign of units and assessment for University publications. **Continuing students** – Collaborating with the Faculty to ensure that curriculum change does not adversely impact student progress. **Using appropriate assessment tools** – Identifying and providing an effective online tool that facilitates assessment of teamwork skills. **Student guidelines and resources** – Generating essential resources for students that support their teamwork skill development. **Marking and grading** – Supporting academic staff to use the assessment tool effectively to analyse and apply student results and calibrate an individual's mark in teamwork. **Academic workload** – Providing just-in-time and personalised support to academic staff taking into account their work pressures and time. **Integrating PODBL implementation** – Alongside implantation of GLOs, there was a requirement for redesigning engineering curriculum using design based projects.
Target and support 'early adopters'.	Ten **early adopters** were chosen based on their interest and the School's planned offering of these units in the implementation of PODBL curriculum. **Needs analysis -** During the design phase we established the needs of these early adopters and prioritised our work to ensure the provision of targeted support. **Professional development** – Provided personalised support to

	redesign assessment, teaching and learning activities, to develop resources for student engagement, to use the assessment tool for engaging students in self- and peer-assessment, to analyse and finalise student results. **Practical support** – In class support that models teaching and learning practice for academics to support student engagement in teamwork tasks. **Review and reflection** – facilitating academic review, and improvements to practice through reflection on student evaluation, self-evaluation, and peer-evaluation.
Celebrate achievements	**Communicating outcomes** – Making academic work public in various forums for reporting back to University Senior Executives. **Encouraging Scholarship of Teaching and Learning** – Collaborating with early adopters to present their work at the University Teaching and Learning Conference. **School celebrations** – Working with the school to organize internal celebrations for acknowledging the early adopters, promoting their success and encouraging others to participate.
Evaluate the impact of our support	**Self-review** - Collecting evidence to measure our success in supporting the academics to integrate teamwork skills in teaching, learning and assessment. This includes, developing academic experience reports, student feedback on the use and usefulness of the tool for self- and peer-assessment of teamwork skills, and development of a plan for continuing support for progressive implementation.

Conclusion

There are many ways to improve teaching and learning performance. An academic's plan for growth provides the need and the context for supporting teaching and learning development (Southwell & Morgan, 2010). We consider that the summary table of our systematic support approach can be utilised in other contexts for managing change. Preparing for change, identifying challenges, targeting and then providing practical support to willing participants, were the fundamental components of our support strategy. Investing quality time in 'early adopters' in the initial stages of the change process, provided the evidence and impetus for shifting the School's culture from a teacher-centred to a learner-centred pedagogical approach. These early adopters willingly engaged with the process to further support change implementation and became the catalyst for change as they shared their positive experience with others, through conversation and presentation. Further work is needed to implement a whole of course approach, scaffolded through clear outcomes and standards at each year level. From our experience, developing a trusted collegial relationship and providing practical support is vital in bringing about change leadership in teaching, learning and assessment practice.

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Transformation in Engineering Education – A Case Study of Remote Learning Experiences in China

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SESSION C1: Integration of theory and practice in the learning and teaching process.

CONTEXT A collaborative teaching program between Deakin University and Wuhan University of Science and Technology (WUST) is a particular realization of a learning and teaching transformation. The collaborative program aims to bring high-quality Australian curriculum standards to mechanical engineering students in Wuhan, China. To maintain collaborative teaching quality, the entire Deakin mechanical engineering program is transformed to the WUST collaborative program.

PURPOSE This study focuses on the quality assurance of teaching in the collaborative program when the learning and teaching process happens outside Australia. When a Mechanical engineering program is offered at a different institution at a different time-span, it requires different learning and teaching support as well as educational settings.

APPROACH To address the first problem of insufficient equipment, we developed experimental equipment that is portable to WUST. To tackle the problem of teaching approaches, we implemented flipped-classroom teaching where equipping students with self-learning skills is emphasised. Quantitative and qualitative questions were given to the students at the end of the trimester teaching to analyse students' experiences and expectations on the implementation of new teaching styles. The outcome of this survey is then fed back to the improvement process of such new teaching styles for the future academic years of the collaborative program.

RESULTS The analysed survey results give an insight into students' perception of the new learning and teaching approaches. The initial results show the overwhelmingly positive reception of the project/design based approach. Obvious quantitative improvements that have been measured are as follows: Students' involvement in classroom/lab activities is improved when compared to that of a previous year cohort with the same activity. The WUST students showed improvement in terms of following along the intensive teaching/learning schedule.

CONCLUSIONS From the survey results, more than 90% of students agreed that the group-based practical activities were most helpful towards achieving the learning goals. The project/design-based learning activities have enhanced students learning capability of understanding practical/theoretical prospects in this course.

KEYWORDS Learning and teaching, collaborative teaching, students' experiences.

Introduction

The field of engineering, like many technical fields, is increasingly working in an international environment. In the Australian context, Australian engineers are increasingly practicing in an international environment. On the other hand, recent years have seen an increase in the number of engineers trained overseas working in Australia. This trend is also seen in higher education, where in recent years, there has been an increasing number of teaching partnerships between Australian and various universities in Asia.

Deakin University in Victoria has engaged in a few international education partnerships for training undergraduate engineers. The first was a partnership between the School of Engineering and IMC Technologies in Singapore to deliver Deakin's undergraduate engineering programme to students in Singapore by means of distance education and intensive on-campus classes in Singapore delivered both by local academics and visiting Deakin academics (Briggs & Chng Han Ming, 1998). Running over several years was a second partnership between Deakin and Kolej Damansara Utama (KDU) College in Malaysia (Selvalingam, Billings, & Booth, 2007).

In 2012 Deakin University and the Wuhan University of Science and Technology (WUST) established a partnership to offer a cooperative BE Mechanical programme in China (Chandrasekaran et al., 2016). The program aims to complement similar programmes operating at WUST, and to give local Chinese students an international engineering education. In this agreement, Chinese students in the programme complete 2.5 years of the course locally in Wuhan. Then they can complete the remaining two years of the course in Australia. Graduates of the program receive a Bachelor of Engineering from Deakin and from WUST. Students are exposed to modern methods of instruction such as cooperative learning and design-based learning. The initial results of the programme indicate that the participating students have an enhanced and satisfactory learning experience (Jiang, 2017). This paper examines the experience of teaching one unit in the programme, SEEW321, Electro-mechanical Systems. It discusses some of the challenges we found in delivering the unit in China and how these challenges were overcome.

Unit Outline of SEEW321 and problem statements

Unit outline of SEEW321

The course is a third-year engineering electro-mechanical unit. This unit is aimed at introducing the underlying concepts combining mechanics, electronics and computing in producing realistic modern day engineering systems. It comprises several main modules including Introduction to Electro-Mechanical Systems and Programming the Programmable Logic Controllers (PLCs).

Topics covered in this unit include: circuit theory, operational amplifiers for analogue signal processing; programmable logic controllers (PLCs) and ladder logic; sensors-position, velocity, encoders, optical pneumatic and hydraulic systems, mechanical actuation; motors-DC, stepper, motor control and computer interface.

Students used these experiences as the starting point for the design and research-based activities, working towards the following Unit Learning Outcomes:

- Gain a basic understanding of PLC programming.
- Use concepts and techniques in electronics to control and design various mechanical systems.
- Obtain an insight into signal conditioning and sensing.
- Provide an understanding into the working of electro-mechanical systems.

The unit has been delivered in both academic years 2016 and 2017. The assessment in the academic year 2016, when the unit is first delivered in China, was designed with most of the focus on assignments and final exam. Particularly in the 2016 curriculum, up to 40% of the final weight was dedicated to written assignments (15% for assignment 1, 10% for assignment 2, and 15% for assignment 3) and 60% of examination.

Problem statements

The unit has been delivered in the collaborative program since early 2016 for a cohort of 40 students. At the end of the teaching 2016 period, a simple evaluation survey was conducted (anonymously) so as to seek students feedback on the unit. The students were primarily asked three questions,

- "What I liked about the lessons (teaching materials and teaching)".
- "What I did not like about the lessons".
- And "what I would suggest to improve the lessons".

A total of 23 students provided feedback out of 40. A variety of remarks were received such as "too many lessons in one week", "give more examples", "provide more realistic examples", "the lesson maybe need some experiments", "the lesson have (no) interaction", etc.

The comments which were mentioned repetitively by students were observed as those might indicate common concerns within the student cohort. Typically, there are a total of seven comments (30%) suggesting to have more practicals and five remarks (21.7%) indicating difficulty to absorb the knowledge in a short period of time.

An investigation into the causes of those concerns of the 2016 cohort was carried out. In fact, even though an engineering unit, there was little experimentation demonstrated to the students. This was due to unavailability of WUST equipment that fits into this Deakin engineering curriculum. Another reason was that there was no existing Deakin equipment which could be used for both teaching at Deakin University and WUST (remote institution). Consequently, this posed a problem of constructing a new experimentation test bench that could be used at Deakin University and portably carried to WUST.

Via examination of the teaching method in 2016, it was obvious that the didactic pedagogy has created passive learning environment within the cohort. Together with a tight schedule – only two weeks of studying for the whole Deakin subject, it caused stress and strain among students who passively strived to follow the intensive schedule. Therefore, the other issue worth discussing is whether we can apply a teaching method that instils students to learn proactively in the intensive teaching mode.

Design-based Remote Learning and Teaching

To address the first problem of insufficient equipment, we developed experimental equipment that is portable to WUST. The equipment satisfies two primary objectives: 1) it is lightweight for the carrying purpose, and 2) it must fit nicely within the curriculum and unit outline of the existing Deakin University unit.

The respective unit earning outcomes require students to have practical capability in programmable logic controllers (PLC) and knowledge on various electro-mechanical signals and systems. An experiment platform training the students towards those outcomes was assembled by recycling existing LabVolt test panels (Festo Didactic Company, n.d.). The platform contains a real PLC and a small-scale wind turbine system as shown in Figure 1.

Not only suitable to training the students to achieve the learning outcomes, the experiment platform is also constructed in a way that is portable. All equipment can be stored in a 57-cm long x 35-cm width x 32-cm height box (Figure 2). As such, the equipment can conveniently be transported between Deakin University and WUST.

In the curriculum, the students work in groups to solve design-based problems constructed around the PLC-wind turbine platform. The basic knowledge of the equipment which is about programmable logic controller (PLC) was presented first. Then students were given design problems, starting from basics, then gradually progressing towards more advanced levels.

(a) The complete platform (b) Students are practicing with the platform

Figure 1: The experiment platform used to train practical capability in SEEW321.

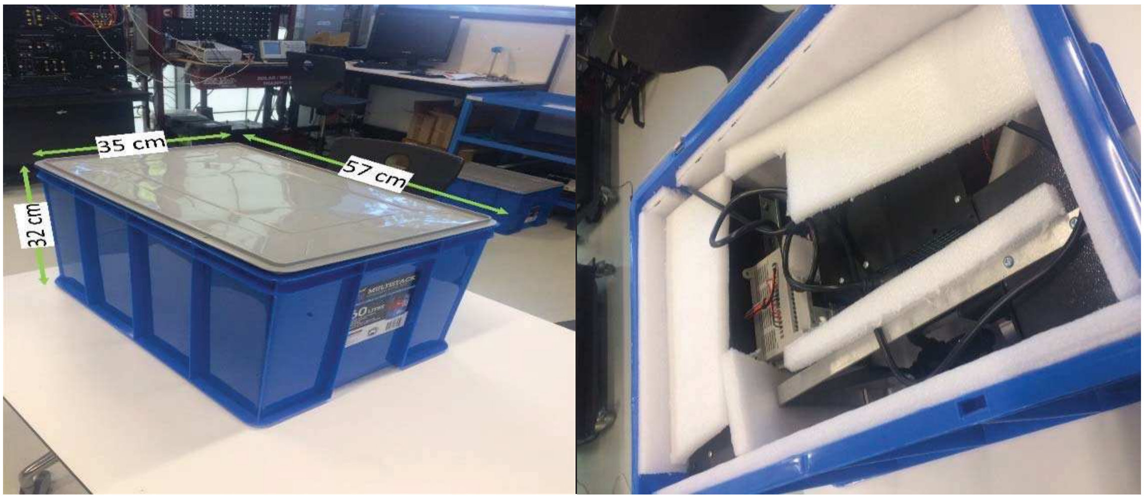

Figure 2: The platform is fit into a portable box (left: the dimension of the box, right: devices arranged in the box).

To address the second problem of teaching approaches, instead of conventional didactic teaching, we carried out flipped-classroom teaching (Velegol, Zappe, & Mahoney, 2015), where equipping students with self-learning skills is emphasised. Students spent their class time engaging in active activities rather than listening to two weeks' worth of intensive lectures. Now students can invest more learning hours into researching directed resources, and then comprehend the new knowledge in a manner consistent with active learning. The steps to carry out flipped classrooms are presented in Figure 3.

Some of the steps in Figure 3 are important. Particularly, the preparation and introductory lectures are vital since students in China are not familiar with flipped classroom teaching. Such beginning lectures prepare the students with this kind of learning and teaching approach which is considered unconventional in China and get the students ready to work in groups. Also, the introductory lecture gives the students an overview of the whole unit contents, the learning outcomes, and assessments so that the students can make plans for their study in this student-focused approach.

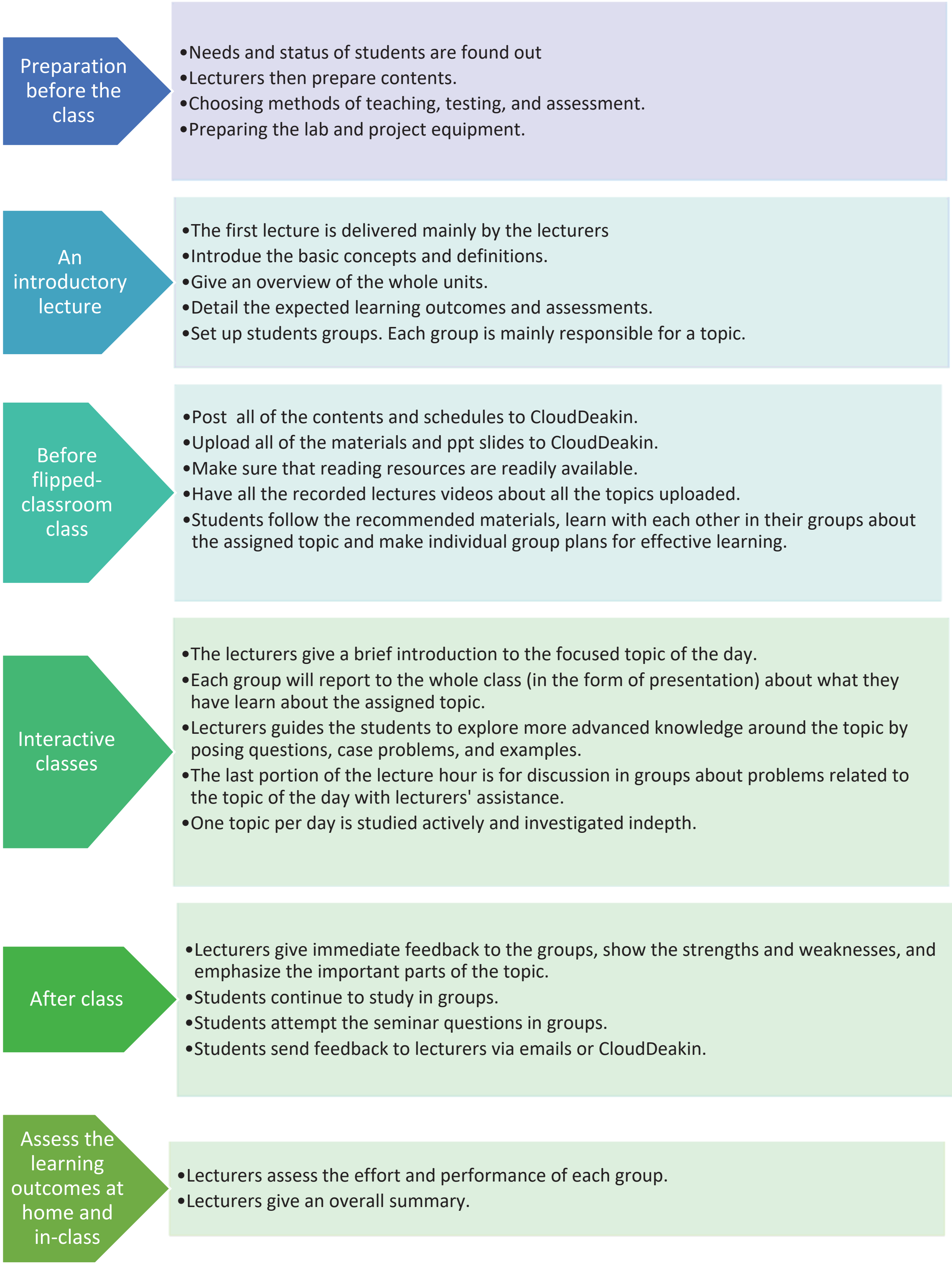

Figure 3: Detailed implementation of the flipped classroom for SEEW321 (after Biggs and Tang, 2011).

Another important step is the presentation (step 4 in Figure 3). Some studies recommend to have in-class discussion. However the students tend to be shy. As being their first time in this approach, they tend to passively listen rather than speaking out. The in-class, group presentation is an ice-breaking technique so as to guide the student to gradually express their opinion publicly and thus actively participate to the learning and study.

The flipped classroom in turn solves the problem of passive didactic learning and facilitates the students' active learning in a short period of time. Even though the whole process takes approximately the same amount of time face-to-face interaction with the students as the didactic, the whole lot of 4 topics of the unit are delivered to the students in an active way. This helps students to avoid the passive-follower phenomenon.

In 2017, in line with the new approach for the collaborative-teaching program, the unit curriculum, especially assessments, is also improved. Instead of focusing purely on the exam and written assignments, assessments on presentation and laboratory practicals are included in the improved curriculum. As such, up to 30% of the final weight is dedicated to assessment of oral presentation and lab work. Assessment also contains 30% of design and analysis assignments, and 40% of examination.

A final remark in this section is that the design of experimentation as well as the flipped classroom are in fact features of design-based learning (DBL) theory. The learning environment assists the curriculum to move into the twenty-first century with students being hands-on in their work. The students develop problem-solving skills, engage in collaborative teamwork, create innovative designs, learn actively, and work with real-world problems. In other words, the implementation of methods presented in this section is actually showcasing an application of DBL. The Table 1 below matches the features of DBL theory (Dopplet, Christian, Schunn, Silk, & Krysinski, 2008) and the teaching and learning methods presented here.

Table 1: DBL learning environment features.

DBL learning environment features	Methods in this section
- A design-based learning curriculum approach in teaching and learning. - Student projects around problem/design activities.	- The construction of the experiment platform and the design problems developed around this experiment platform.
- Team-based learning/collaborating learning in classroom seminars.	- The flipped classroom techniques in which students work, discuss, and present in groups. - The practice of lab practicals and cooperation in groups to solve design problems.
- Teaching and learning assessments/evaluation processes.	- Assessments for presentation, practicals, design assignments, and exam.

Methodology

To assess the efficacy of the proposed teaching and learning approach, perspectives of the students about the proposed approach are obtained. The students' perspectives are also important for staff to improve the teaching and learning approach for this international collaborative program. In this research, a paper-based survey with both quantitative and qualitative questions was utilized to capture the students' perspectives on the unit.

Table 2 shows the survey questions used in this research. The questions are constructed to determine the students' experience of their third-year undergraduate engineering within an international collaborative context. The questions are also designed to facilitate the quantitative and qualitative analyses of the students' perspectives about the design-based approach embraced in the delivery of SEEW321 Electro-mechanical Systems in 2017. Furthermore, challenges to the new teaching and learning approach was identified at the same time via the survey.

The entire cohort of 60 students in their third-year study was asked for their perspectives and level of experience. The survey was conducted anonymously and in a way that students' names are unidentifiable. Results of the survey would present students' own experiences as well as various views of the unit and the course. Such views and experiences also encapsulate knowledge and expectations of the students.

The survey also served the purpose of informing the collaborative teaching program any evolved issues and in turn enhancing the student experience of the program.

Abiding ethics process and procedure, the research survey was conducted only by a third party. Without the involvement of the unit chair and related academics, the students are surveyed with the following questions:

Table 2: Questions for the student survey.

1. Are you motivated to learn and achieve the learning goals in this design based learning unit?
2. Do you feel comfortable to participate and interact in the practical activities?
3. Are the individual/group based practical activities most helpful to achieve learning goals?
4. Do the practical activities help you to practice and obtain design (coding) skills?
5. Do the practical activities help you to practice and obtain problem-solving skills?
6. Do the practical activities help you to practice and obtain communication skills?
7. Do the practical activities help you to practice and obtain team-work skills?
8. Do you enhance your self-study skills by being involved in the flipped classroom teaching approach?
9. Overall are you satisfied with the new teaching approach (practical and flipped classroom)?
10. Does the practical activity task enhance your learning when compared to traditional lecture classes?

Survey Results

A total of 41 students participated in the survey. The students' perceptions on their learning experience are shown in Figure 4. For all the questions, the most common response was agreement. The most questions with which students agreed were questions 1 and 3. A total number of 96% of students agreed that the design-based learning unit had motivated them to achieve the learning goals. 98% of students agreed that the group-based practical activities were most helpful towards achieving the learning goals. These results reflect the fact that the students in China where the conventional theory-focused teaching is embraced have a strong desire towards practical and design-based curriculum.

Around 12% of students disagreed that their self-study skills are enhanced by participating in the flipped classroom teaching approach. The student responses to question 8 indicated that the students still find communication an issue for them in the learning environment. Moreover, since many students experience for the first time active learning, and since all the classes are conducted in English rather than in the native Mandarin, the benefits of flipped classroom are not yet fully comprehended. This area should be investigated further to better understand the underlying reasons for the high number of disagree responses.

The student responses to questions 2, 9 and 10 in the survey were similar. The combined number of agreed responses for these questions ranged between 93-98%. We can say that of the students surveyed, they felt similar about being satisfied with the teaching method and also that the practical activity task had increased their learning compared to traditional learning. Also, the students generally felt comfortable in participating and interacting in the practical activities. That being said, there remains 7% of students, especially in Q9, who were not comfortable with the new learning environment. Future offerings of this course will address this to increase student satisfaction. When students were asked about what skills they obtained from the practical activities, again most of the responses clustered towards the agree response.

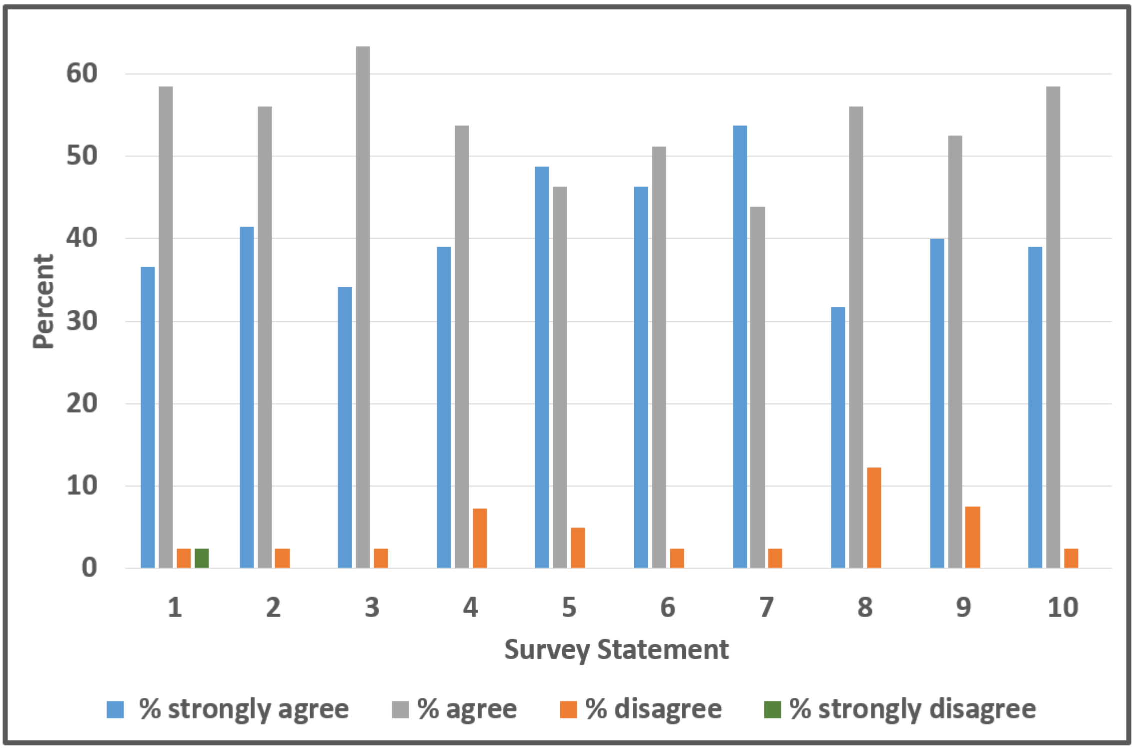

Figure 4: Results of the student survey.

Discussion

At WUST, students are exposed to an international experience of learning engineering professional knowledge and technical knowledge through this collaborative-teaching program. Changing the way of learning will change the students' behaviour in acquiring the values and culture for future career readiness. As an attempt of transformation, in this particular unit we have tried few processes of changing the classroom teaching towards a flipped classroom, along with a portable laboratory facility for students to work on design problems in teams.

It is not only bringing international values to the Chinese students. The motivation of collaborative teaching is bringing understanding and shared values between staff and students. The shared values will create a strong culture for a sustainable educational philosophy. In the process of transforming education, students should able to develop their own learning goals. To select their own learning goals, students should analyse problems and frame questions with respect to the information they lack to solve the problems. Gardner and Hatch (Gardner & Hatch, 1989) state that "intelligence is the capacity to solve problems". Therefore, "students should learn to integrate knowledge from different disciplines and learn to select methods, theories and tools to come up with a solution that is based on the chosen problem" (Jonassen, 2014).

The results show a clear set of positive student satisfaction for the Deakin University engineering design course they had recently completed at the remote institution (WUST). The results in this paper are in line with previous results reported in both Bishop & Verleger (2013) and Scott, Khoo, Peter, & Round (2016), in which significant student preference for the active learning mode is indicated. Furthermore, WUST students' positive response to the design-based and practical curriculum aligns with a recent engineering education research (Wordley, Jones, Taylor, & Pearson, 2016) where more than three quarter of the surveyed students said that they had improved understanding of concepts by spending more time on actively solving design problems. Therefore, the research in this paper implies that the active learning and design-based curriculum make students more satisfied with their learning outcomes irrespective of the geographical difference, i.e. the approach is applicable not only in Australian context but also at overseas institutions of collaborative teaching programs.

There are still some limitations. These limitations are worth being investigated further to make the remote DBL more complete. For example, 12% of students disagreed that their self-study skills are enhanced by taking part in the flipped classroom. Anecdotal evidence has suggested that students in China, besides being acquainted to and comfortable with passive learning, still find it difficult to communicate in English with Australian lecturers. The communication barrier has led to some of the students not to seek guidance from the Australian lecturers. Consequently, the benefits of active learning are not fully comprehended by the students. More surveys and quantitative analyses into this problem should be done in the future so as to resolve the issue. Further work will include a detailed survey of best practice in teaching to off-shore and international cohorts, and intensive training for the teaching staff who travel from Australia to China.

Another limitation is that there are budget constraints in the program that hinders development of portable lab equipment. Therefore, it is not easy to expand the approach proposed in this paper to other units of the WUST- Deakin program. Deakin University, is trialling remote laboratories in which the students via internet are able to remotely conduct experiments and answer design problems. However, this remote-lab solution is difficult to be applied in China due to the slow and unreliable internet connection between China and Australia.

In the future, the following work is proposed to find solutions for the issues:

- Carrying out more surveys to find a way to help students immerse themselves better into the active learning approach.
- Expand the flipped classroom and DBL approach to other units of the collaborative teaching program.
- Instead of making portable lab equipment which is more expensive, more mobile phones apps can be developed for the teaching at both Deakin University and the remote institution.

Conclusion

As part of a joint undergraduate mechanical engineering course offered by Deakin University and Wuhan University of Science and Technology, a third-year unit on electro-mechanical systems has been taught in 2016-2017. Problems with teaching practical skills and maintaining student engagement led to two significant pedagogical changes for 2017. Firstly, a flipped-classroom, design-based teaching approach was adopted, and second, portable lab equipment was brought from Australia to China to give the students some hands-on learning experiences. A survey of students given at the end of the 2017 delivery revealed that students overwhelmingly welcomed the changes to how the unit was delivered in the two-week period of instruction by the Deakin lecturer.

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Pointers to Conceptual Understanding

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CONTEXT
Concept inventories are tests used to elicit student misunderstandings and misconceptions. Traditionally, they exist as a set of multiple-choice questions (MCQs), including the correct option, as well as some distractors (Libarkin, 2008). This multiple-choice format allows for faster marking and feedback; however, it does not identify conceptual misunderstandings, or if a student has guessed the correct answer. By adding a space for students to add a textual justification (Goncher, Jayalath, & Boles, 2016), their answers can be checked to ensure that the concepts are correctly understood.

PURPOSE
Automated textual analysis will allow insights to be uncovered, and to help speed up the process of grading to give feedback to students and informing educators. As part of that process, we endeavour to address the following questions:
1. What pointers can be identified that indicate a student's conceptual understanding?
2. What conclusions can we make from these identified pointers to conceptual understanding?

APPROACH
Over the past four years, two concept inventories have been deployed, both with multiple choice questions, as well as a free text field for students to give reasoning and explanation. We will combine several machine learning techniques to analyse the textual response data, including:
- Word2vec – which allows words to be modelled as vectors, for easier computation (Mikolov, Chen, Corrado, & Dean, 2013)
- LDA (Latent Dirichlet Allocation) – Allows classification and grouping of topics and areas (Blei, et al., 2003)
- SVMs (Support vector machines) – which allow classification to be performed and similar areas grouped

RESULTS
Four pointers were identified to help to automatically determine if conceptual understanding is present. The first three pointers can be determined with certainty, the fourth "validity of the response" is one that is traditionally determined by a human marker. Comparing with an expert marked dataset, the algorithm to determine this pointer achieved a 75% accuracy.

CONCLUSIONS
Using the four identified pointers we are able to detect if a student has correctly identified the concept which they were being tested for in a particular question. The four pointers, allow some leniency if one of these is not achieved, and can also allow us to draw conclusions as to where issues lie in a student's understanding. This presents several opportunities for benefits such as individualised feedback for students and entire class feedback for educators.

KEYWORDS
Concept Inventories, Textual Analysis, Conceptual Understanding, Misconceptions, Machine Learning

Introduction

Formative assessment can be a strong contributor to enhancing students' learning outcomes, especially if these are used to provide them with meaningful and timely feedback. Nevertheless, for lecturers, this process can be very time consuming, and may even become impractical for large classes. One approach to reduce the marking load is to use Multiple Choice Questions, MCQs, which can be automatically marked. However, questions or assessments that require text-based answers can provide more information about students' understanding compared with standard MCQs (Birenbaum, 1987; Popping, 2012).

In order to better assess students' conceptual understanding, our study focuses on automating the collection and analysis of students' written textual responses, together with their MCQs selected answers. In our approach, we utilise text analysis and machine learning techniques to process the information gathered from students' textual responses.

Concepts

Concepts are representations of ideas in a simple form (Zirbel, 2006), and being the foundation or building blocks for an entire subject, they lie at the core of developing student understanding. Examples of concepts within the STEM area include: Time, Magnetism and Energy. These concepts, represented in a simple form, can appear easy to grasp however, many students fail to develop accurate understandings at school and can become confused and disenfranchised when successive ideas are introduced at university. Educators need to identify student misconceptions as they arise so that they can address them in their teaching. Understanding of concepts also allows for a deeper knowledge gain, as opposed to a more surface based approach. Concepts can also be defined in many ways, and this is just one example.

Assessing Conceptual Understanding

Assessing the conceptual understanding of a student can be a time consuming task, and responses need to be interpreted by a marker who is knowledgeable in the content area. Concept inventories were designed to help alleviate this issue, using a series of multiple-choice questions. They are designed to include the correct option, as well several distractors (Libarkin, 2008) however, one of the drawbacks of concept inventories is that they need to be designed by experts (Arbogast, 2016), and usually are designed to test specific concepts within an identified domain, e.g. signal processing.

Building on previous work (Cunningham-Nelson, Goncher, & Boles, 2016) further textual data has been gathered from another cohort of electrical engineering undergraduate students. We have selected a single question from the Signals and Systems Concept Inventory to investigate further.

Signals and Systems Concept Inventory

The Signals and Systems Concept Inventory (SSCI) was developed to assess core concepts in undergraduate signals and systems courses. The continuous-time and discrete-time versions are validated 25-question multiple-choice exams, which assess certain signal processing concepts in the continuous- and discrete- time domains. Potential solutions for every question include distractors (incorrect selections) that assist in determining the type of misconception a student may hold for each concept (Wage, Buck, Wright, & Welch, 2005). Developers of the SSCI determined and refined the distractor selections through the administration of earlier versions of the test. The SSCI was also designed to include a set of synthesis questions, which linked and built on several questions in the SSCI, and questions that require reverse reasoning. Additional details regarding the SSCI and its developers can be found at: http://signals-and-systems.org.

We utilised the discrete-time version of the SSCI in this paper, and examine how to accurately evaluate student conceptual understanding using the SSCI questions. In this study, students provided a multiple-choice response for each question and a written explanation as to why they selected the specific multiple-choice option. Previous studies utilising the augmented SSCI (multiple choice selection plus written response) have investigated the text evaluation processes and insights into students conceptual understanding not possible with MCQ-only questions (Goncher, Jayalath, & Boles, 2016; Boles, Goncher, & Jayalath, 2015).

The SSCI Discrete-time test has seven conceptual areas, i.e. math, linearity time invariance, sampling, filtering, transforms (time / frequency), convolution, and transform properties. We present an example from the SSCI Discrete-time to highlight example concepts, distractors, and student responses. Question 1 evaluates whether students can identify the sinusoid $\cos(\pi n)$ as having the highest frequency. Distractors include three signals that have obvious sinusoidal shapes, but tests if respondents confuse high amplitude with high frequency or large period, and if the sampling rate impacts the respondent's selection.

Question 1: The plots show segments of four periodic signals, all on the same time and amplitude scale. Each of the signals has the form $\mathrm{A}\cos(\omega_0 n)$ *with* $-\pi < \omega_0 \leq \pi$. Which signal has the highest frequency?

Question 1 on the discrete-time version is more difficult than the continuous-time version however 89% of respondents answered correctly. Correct example responses included, *"It has the shortest period and thus the highest frequency"* and *"The frequency is how fast something takes to complete one wavelength. A) takes 10s. C) takes 10s D) takes 20s B) takes <2.5s"*.

The example text responses illustrate how students can arrive at the correct multiple-choice answer, but have varying explanations. The first response highlights the relationship between frequency and period using the terminology, and the second example looks at each selection as a case of how long it takes before the signal repeats itself. One of the incorrect responses, e.g. *"amplitude of the cos wave is the frequency, the largest amplitude is the largest frequency,"* confirms potential misconceptions identified by the SSCI developers. Another respondent with an incorrect response, "*Has the highest and lowest points,*" also had the same misconception but did not use the specific terminology of amplitude in the text. The multiple-choice selection plus text responses show that students can arrive at either correct or incorrect answers, but may have varying ways of explaining the understanding, or misunderstanding of a concept.

Machine Learning and Text Analysis

In this work several text analysis and natural language processing techniques are used. These are combined with machine learning algorithms, to predict a particular outcome. Some key terms and processes used are discussed below.

LDA (Latent Dirichlet Allocation)

Latent Dirichlet Allocation is a probabilistic model for a collection of data, such as text (Blei, et al., 2003). Using a Bayesian technique data can be modelled and grouped. In terms of a text corpora, this means grouping topics and words together to obtain keywords. One common application for this, is automatically assigning labels to a large document which would otherwise need to be manually labelled.

Word2vec

Word embedding allows words to be modelled in a vector space. When viewing words in a vector space similar words will appear close to another, and relationships can be represented by addition and subtraction operations. To create the word vectors, a pre-existing model trained using many news articles was used (Mikolov, Chen, Corrado, & Dean, 2013). This model allows relationships between many English words to be preformed, and can be used to help with meaning in this analysis.

Research Questions

Taking advantage of the careful design of the concept inventory questions multiple choice questions and students' free text justifications, we aim to identify key parts of responses, and checkpoints which might tell an educator about a student's learning progress. Automated textual analysis will help speed up the process of grading and giving feedback to students and educators. As part of that process, we endeavour to determine:

1. What pointers can be identified that indicate a student's conceptual understanding?
2. What conclusions can we make from these identified pointers to conceptual understanding?

Method

Pointers to Conceptual Understanding

Identifying students' conceptual understanding is not a straight forward process. When a student's free text response to a question is being marked, generally, a marker will have key aspects and terms in mind, and several "model solutions". This however becomes more difficult when marking responses automatically. Having both the multiple choice and short response data available allows further insights into a student's understanding. We have defined four pointers or indicators, which we believe, used together, will provide an indication of conceptual understanding.

Pointer 1 – Multiple Choice Correct

Utilising concept inventories which have carefully crafted questions and answer options allows common misconceptions to be identified using the multiple choice option selected by students. The multiple-choice response chosen is one pointer towards a students' correct understanding of a concept. This multiple-choice option can be easily marked by a computer, and makes this first pointer straightforward to obtain.

Pointer 2 – Concept Mentioned

For this we need to first know which are the key concepts within the questions. This can be done either by defining these manually for the questions, or by using methods such as LDA to perform entity extraction automatically. After the topic is identified, we can then perform a keyword match to find the keywords that occur in particular responses. If the concepts are mentioned, then we can say this pointer has been met.

Pointer 3 – Response Uncertainty

In their responses, students were asked to use words such as 'guess' or process of 'elimination' to explain how they come to their answer. If these words are mentioned within a students' response, this adds doubt to the level of certainty and confidence in their answer. This is something that is important to consider when performing analysis on a student response. It is also important to consider the difference between the two words. We considered that responses which include the word "guess" are more uncertain than those which have the word "elimination".

Pointer 4 – Free Text Validity

This is the most difficult pointer to determine, and results will vary. The validity of the written response would traditionally need to be evaluated by a human marker. The marker will compare the given response to a model or bank of model responses or their down expert knowledge of the subject. However, this needs to be done in an automated fashion. Using several machine learning methods, we aim to replicate this manual process.

Responses for Q1 of the SSCI were initially manually labelled (marked) into three categories:

1. Concepts mentioned and correctly used
2. Concepts mentioned, but incorrectly used, or incorrect
3. Answer incorrect or major misconception.

These responses were manually labelled to be used to train and validate the machine learning algorithms evaluated for this task. We start with the text responses given by students and perform some initial pre-processing of the text to ensure that the text is ready for analysis. This involves: transforming all the text to lowercase, moving stop words (i.e. it, and, the) and lemmatising the words (using the base of each word).

The sentences are then converted into a “bag of words” model for processing. A bag of words model (word frequency model) means that each sentence is converted into a row of ones and zeros. All the sentences together form a sparse matrix, which can be quite large however this sparse matrix is the input into various machine learning classification methods. This bag of words representation is then passed into various machine learning classifications methods mentioned below (Boser, Guyon, & Vapnik, 1992; Ray, 2017). The preliminary results can be seen in Table 1.

Table 1 – Bag of Words Accuracies

Method	Extra Trees Classifier	Linear Discriminant Analysis	Logistic Regression	KNN	DT	Naïve Bayes	Linear SVM	Gaussian SVM
Accuracy	68.9%	58.0%	71.8%	64.9%	64.9%	56.9%	71.2%	**74.1%**

Table 1 shows that the Gaussian SVM classifier produces the best results (most correctly classified responses). Using word2vec, representing the word responses as vectors, the average word vector for each response can be found. This word vector was used with the Gaussian SVM classification method above. This achieved a classification accuracy of **77.0%**. This classification model was then used for predicting the outcome autonomously for pointer 4.

Results

Overall Results

Initially results were examined for each pointer separately. These results have been summarised in four separate tables, to reveal how the group of students performed across each pointer for Q1 of the SSCI.

Pointer 1 – Multiple Choice Correct

The multiple-choice results show a good initial result for class understanding as a whole. Table 2 below shows a count and percentage for both incorrect and correct results from the multiple-choice answers. We can see that most students answered this question correctly, and would hope that these students understand the concepts in the question. We can investigate this further, looking at the remaining three pointers.

Table 2 - Summary of Multiple Choice Results (N=174)

	Count	**Percentage**
Correct	155	89.1%
Incorrect	19	10.9%

Pointer 2 – Concept Mentioned

The second pointer identified was whether students mentioned the key concepts for the particular question. The key concepts that were required in a response could be determined in one of two ways. One option is for the concepts to be identified by someone familiar with the topic area or subject. For example, for the chosen question, three important concepts were identified: Frequency (freq), Period and Time.

The second option is to use the LDA method to automatically identify topics within a document can be identified. Providing all the student responses as input into the LDA algorithm, topics can quickly be extracted. In this case, the top three topics grouped by single words identified were: “period”, “signal” and “b”. Interestingly if the topics are grouped into a larger number of words, further patterns emerge, such as the words “highest, frequency, and b” being grouped into one topic. These show key terms which we might expect in a correct response.

Table 3 shows a count of the responses which mentioned the manually chosen keywords: frequency and period. Interestingly this number is significantly smaller than the number of students who got the multiple choice option correct. Whether the student mentioned one of the desired concepts is another pointer for correct understanding.

Table 3 - Summary of Concept Mentioned Results (N=174)

	Count	**Percentage**
Concept Mentioned	123	70.7%
Concept not Mentioned	51	29.3%

Pointer 3 – Response Uncertainty

A further pointer for students’ conceptual understanding is the certainty in their answer. If a response mentions “guess” or “elimination”, it can indicate little or no confidence in the response. Doubt expressed in a student response could indicate a possible misconception, or a lack of complete conceptual understanding. Table 4 shows a summary of these results, with a breakdown of certainty within the various levels. It can be seen from this table that most students are certain in the answer that they select.

Table 4 - Summary of Uncertainty Results (N=174)

<table>
<tr><th colspan="2"></th><th colspan="2">Count</th><th colspan="2">Percentage</th></tr>
<tr><td rowspan="2">Students Uncertain</td><td>Elimi</td><td>1</td><td rowspan="2">7</td><td>0.6%</td><td rowspan="2">4.0%</td></tr>
<tr><td>Guess</td><td>6</td><td>3.4%</td></tr>
<tr><td colspan="2">Students Confident</td><td colspan="2">167</td><td colspan="2">96.0%</td></tr>
</table>

Pointer 4 – Free Text Validity

The final pointer towards assessing conceptual understanding, and arguably the most important is the free text response written by the student. A valid response from a student is one that demonstrates full conceptual understanding, whereas misconceptions or a lack of understanding can also be determined. Using the prediction methods previously discussed, Table 5 shows a summary of these results. These provide an overall picture of the understanding of the desired concepts in this question.

Table 5 - Summary of Validity Results (N=174)

	Count	**Percentage**
Concept correctly used	130	74.7%
Concepts mentioned, but incorrectly used	20	11.5%
Answer incorrect or major misconception.	24	13.8%

Selected Examples

Overall analysis can provide a good pointer to the overall level of understanding in a group of students and looking at individual responses allows conceptual understanding to be examined on a student by student basis. Selected examples of responses have been chosen to show the possible conclusions that can be drawn from the analysis. For each example, the automated outputs will be given, and explored. These chosen examples will hopefully demonstrate where the automated process can succeed, but also where it can be improved.

Selected Example 1

The first example selected, given by a student is, *"guess"*.

Using the automated methods above, the following outcomes are achieved for the four identified criteria as shown in Table 6.

Table 6 - Selected Example 1 Automated Results

P1: Multiple Choice	P2: Concept Mentioned	P3: Certainty	P4: Explanation "valid"
✗	✗	✗	✗

From these four criteria, we can reasonably determine that the student had no understanding of the required concepts. This is evident by their short response, and no explanation.

Selected Example 2

The second response selected is, *"Frequency is defined as number of cycles per second. plot b has the most number of cycle within a one time period."*.

Table 7 shows the outcomes for each of the four pointers. Each of the pointers to conceptual understanding has been met, demonstrating that the student understands the concept being tested. This can be verified by reading the students response and comparing it to the previously given model answer.

Table 7 - Selected Example 2 Automated Results

P1: Multiple Choice	P2: Concept Mentioned	P3: Certainty	P4: Explanation "valid"
✓	✓	✓	✓

Selected Example 3

The third student response selected is, *"Most changes between pos & neg in given time scale"*.

The results in Table 8 from the four pointers show that the student correctly met the first three pointers, but did not meet the final one. However, upon reading their response, we can say that their explanation is valid and demonstrates understanding even though this response is quite different from the "typical response" that is expected. Therefore, a response obtaining the first three pointers, but missing the third should be manually reviewed to check the automated classification of the third response.

Table 8 - Selected Example 3 Automated Results

P1: Multiple Choice	P2: Concept Mentioned	P3: Certainty	P4: Explanation "valid"
✓	✓	✓	✗

Selected Example 4

The final response selected is, "It has the highest density of wave"

Table 9 shows that the student met two out of the four pointers outlined for conceptual understanding. They did select the correct multiple choice option, and expressed no doubt about their answer, however they did not mention any of the listed concepts, and their explanation was not deemed to be correct. This indicates a possible need to reinforce required concepts.

Table 9 - Selected Example 4 Automated Results

P1: Multiple Choice	C2: Concept Mentioned	C3: Certainty	C3: Explanation “valid”
✓	✗	✓	✗

Conclusions From Combinations of Pointers

The four selected examples and out conclusions are summarised in Table 10. When trying to determine conceptual understanding, the information from each of the four pointers can be used. A few combinations have just been chosen to demonstrate the four pointers listed here.

Table 10 - Combinations and Conclusions from Pointers

P1: Multiple Choice	P2: Concept Mentioned	P3: Certainty	P4: Explanation “valid”	Overall Conclusion
✗	✗	✗	✗	No understanding at all of concept
✓	✗	✓	✗	Possible misconception, since they have keywords or a correct response
✓	✓	✓	✗	The first three pointers lead to a need to double check the text response manually
✓	✓	✓	✓	Student has full understanding of concept

Conclusions and Recommendations

This paper presents four pointers identified to assess conceptual understanding. Data was gathered across a four-year period, using a multiple choice concept inventory with added text responses. Using the four pointers identified we can make conclusions about the understanding of the student for the particular question. All of the four pointers are automatically evaluated using a combination of text analysis techniques and machine learning methods. The first three points can be determined with certainty, the fourth “validity of the response” is one that is traditionally determined by a human marker. Compared with an expert marked dataset, the algorithm to determine this pointer achieved a 75% accuracy. One interesting note to make, is that the number of students who selected the correct MC option is significantly more than the number of students who explained in words the correct response. This emphasises that the combination of MCQs and short responses helps to test conceptual understanding.

We have conducted our investigations on one question as an initial study. Further work includes looking at how other types of models may help to improve the prediction accuracy for pointer 4. Models such as recurrent neural networks take word order into account, which our current prediction model does not. It would also be beneficial to consider ways which the combinations of pointers present or not present can be used to give individual feedback to students.

Using text analysis and machine learning methods, we were able to assess to a certain degree, a student’s conceptual understanding of the presented topic. Using the four identified pointers we are able to detect if a student has correctly identified the concept they were being tested for in a particular question. This presents several opportunities for benefits such as individualised feedback for students and entire class feedback for educators.

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Staff competencies/capabilities required and challenges faced when delivering project based learning courses

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CONTEXT
Project based learning (PBL) courses are becoming more popular in engineering programmes but, when implementing this new style of teaching, it can be difficult to anticipate what competencies/capabilities are needed by staff delivering these courses and what challenges they will face. In 2012 Massey University implemented a 'project spine' that consists of a series of PBL courses throughout the Bachelor of Engineering and Bachelor of Food Technology programmes. Since the implementation of the project spine 5 years ago, staff have gained useful practical insights into the delivery of PBL courses.

PURPOSE
The purpose of this research was to collect insights from staff involved in the delivery of PBL courses with a particular focus on understanding what competencies and capabilities staff view as being important, and to identify unique challenges staff have faced when delivering PBL courses and determine areas for further improvement.

APPROACH
All staff involved in delivering project spine courses (including co-ordinators, teachers and supervisors) were invited to participate in an initial online survey. This consisted of a series of questions to determine the importance of a range of different competencies/capabilities on a Likert scale. The questions were related to relevant graduate competencies and the expected benefits of PBL reported in literature. Staff were then asked what challenges they had faced when delivering PBL courses. It was anticipated that the mode of teaching and issues with student teams would be key challenges, based on previous experience as well as the issues reported in literature, so additional open-ended questions were asked on these topics. These were analysed using Affinity Diagrams to provide common themes.

RESULTS
The staff competencies/capabilities which were rated as most important were a willingness to learn as well as teaching experience, while those that rated lowest were industry experience and an understanding of teaching theory. It is interesting to note that teaching experience was seen as one of the most important attributes while an understanding of teaching theory was one of the least important given the change in teaching style required in adopting PBL. The most common challenges with PBL were related to group assessment, the different way of teaching, as well as course organisation and administration. The majority of staff reported that they 'sometimes' experienced problems with student teams and that these tended to be due to a single student either not putting in the effort or not being as capable as the other team members. The most common solution to these issues was via discussion/mediation.

CONCLUSIONS
The two key areas which require further improvement are the allocation of marks to individuals for group work, and the challenges international students face in PBL courses, and managing the solutions consistently across the programmes. The staff perspectives reported here will be valuable for other institutions implementing PBL courses within their engineering programmes.

KEYWORDS
Project based learning; professional development; staff competencies; staff capabilities

Introduction

Several international studies have found that today's engineering graduates require a broader perspective in terms of social, environmental and economic issues, lack teamwork and communication skills and, that while they have a good knowledge basis, they lack the ability to apply their knowledge in a practical way (Mills and Treagust, 2003; Nair *et al.*, 2009; Male *et al.*, 2010). One technique to enhance these skills is the use of project based learning (PBL). PBL typically involves small groups of students working together under the supervision of staff on a long term project (i.e. one semester or more) (Mills and Treagust, 2003). This approach to teaching encourages the students to be more active in their learning and promotes critical and proactive thinking (Hadim and Esche, 2002), all of which are key skills needed in graduate engineers (Goodyer and Anderson, 2011).

Following a substantial review (Goodyer and Anderson, 2011), Massey University implemented a 'project spine' that consists of a series of PBL courses throughout the four-year Bachelor of Engineering and Bachelor of Food Technology programmes in 2012. The project spine consists of one PBL course per semester for each of the first two years and one PBL double semester course for each of the third and fourth years (representing 25% of the programme). These courses focus on developing professional skills required by engineers, which includes communication skills, team work, project management, and the practical application of theory learnt in theoretical courses. In the project spine, projects narrow in focus from global perspectives in Year 1 to major specific Capstone projects in Year 4 (the final year), with increasing autonomy in management of the projects by the students themselves, and increasing level of ability in professional skills (Figure 1 of Tunnicliffe and Brown, 2017). The projects are common to all majors in Years 1 and 2, but are increasingly major specific in Years 3 and 4.The PBL style of teaching is quite different from traditional courses. Typically, a team of staff are involved in the delivery of these courses. The different roles involved are coordinators, teachers and supervisors, where staff may have more than one role in the course. Coordinators plan the course curriculum and administer the course. Teachers will present content that is outside of subject courses needed for the project. Supervisors meet weekly with teams to check progress, advise on direction, and monitor the teams for issues. All staff can be involved in assessment. Typically there are about 4-5 staff involved in a particular course.

Cohort sizes are about 150 (Engineering and Food Technology) across two campuses, students ranging in age from late teens to early twenties but also including some mature students. Staff coordinate, teach or supervise on their home campus, with some intercampus teaching and there is an overall coordinator for the course. Typically teams have four students (range is 3-5). Project courses take place on a single day of six hours in the students' timetable, called the 'project day'. This day is used for any content delivery, assessment, supervision and project work and no other courses are scheduled for this day. Students are also expected to spend an equivalent time outside the project day working on the project. Moodle websites are used for project information, notes and assignment submission. The first year courses have been described previously by Dahm and Anderson (2013) and Shekar and Tunnicliffe (2017). Courses evaluations are completed by students at least every two years and courses are reviewed across campuses annually.

The curriculum redesign focused on PBL as this was an effective method of implementing the CDIO syllabus (Goodyer and Anderson, 2011). Broadly the projects take place over an extended time period (a semester or double semester), they require the application of knowledge from their subject courses (in the current or previous semesters), and the project team has to manage their time, roles in the project and resources to deliver the completed artefact (e.g. design or model), features that differentiate Project Based Learning from Problem Based Learning (Mills and Treagust, 2003, Palmer and Hall, 2011). However it might be argued that Year 1 in particular has characteristics of Project-Assisted Learning or

Problem Based Learning as there is greater direction and content delivery from staff than in later years (Palmer and Hall, 2011, Mills and Treagust, 2003).

The majority of research focuses on the theory rather than the practical realities of PBL courses. Very few studies have examined what competencies and capabilities are required by staff in order to effectively deliver these PBL courses even though staff are known to be incredibly important to ensure the success of these courses (Hung, 2011). During the five years since the implementation of the project spine, Massey University staff have gained useful practical insights into the delivery of PBL courses. The purpose of this research is to capture this information to inform others of this knowledge and to identify key areas that could be further improved.

Methodology

All staff involved in the delivery of the project based courses (co-ordinators, teachers and supervisors) were invited to participate in an anonymous online survey. This research was reviewed and approved by the Massey University Human Ethics Committee, Application SOB 17/15. The survey was administered by an independent person and all identifying information was removed before the researchers were given access to the data. This initial survey was used to gain insight of issues that the staff delivering these courses might have, or capabilities that might be perceived by staff to be missing, and needed further investigation. The results are intended to direct further research, using focus groups and individual interviews, on the important findings from this survey to further develop PBL at Massey University and, improve the Engineering and Food Technology programmes.

The survey first asked the staff to rate the importance of the following competencies/capabilities in terms of their importance, in order to effectively deliver project based spine courses: industry experience, experience managing projects, experience managing people and teams, an ability to counsel and mentor, and technical knowledge specific to the project content/context. The graduate attributes of the Washington Accord (IEA, 2013) pertaining to Professional Skills such as “9 Individual and Team Work”, “10 Communication”, “11 Project Management and Finance”, and pertaining to the design of artefacts such as “1 Engineering Knowledge.” and “3 Design/Development of Solutions” are characteristic of project based learning (Mills and Treagust, 2003, Palmer and Hall, 2011). These are common learning outcomes for project courses, and therefore the survey should look at knowledge and experience in professional skills (project/people management and teamwork, technical knowledge of the project context). The projects are intended to reflect industry (Goodyer and Anderson, 2011), therefore, the opinion of staff was sought to see if this was important. Staff also rated teaching experience, an understanding of teaching theory, a willingness to learn and, a willingness to innovate. It was considered that teaching experience and teaching theory should be considered as the project-based courses reflect a change to a learning centred approach in course delivery, and previous research had suggested that quality teaching would occur with a change in staff conceptions about teaching (Kember and Kwan, 2000). This suggested staff have to learn and innovate to deliver the courses, and reflects attribute 12 (lifelong learning) of the Washington Accord (IEA, 2013).

Finally staff rated the need for a common mind-set within a particular course; and a common mind-set within the entire project spine, as student surveys show, for example, that differences in staff expectations of what is to be delivered in the project cause confusion for the students.

These competencies/capabilities were rated on a five point Likert scale with the options very important, important, moderately important, slightly important and not important available for selection. Staff were also asked for any additional competencies/capabilities that they felt were important.

The survey also asked staff what the key challenges are that they have faced when delivering project based courses. It was anticipated that common issues would include: the different mode of teaching since most staff also delivered traditional content-based courses, and issues with student teams, which was based on the authors' experience and previous work (Dahm and Anderson, 2013, Lima *et al*. 2007). Additional open-ended questions were asked in these areas.

Staff were asked their preferred mode of teaching as different project based courses are delivered in different ways. The options given were: all staff (teaching and supervisors) present throughout the project day, separate teaching and supervision sessions, other (please explain) and no preference.

The survey then focused on student teams as issues with student teams are well known (Dutson et al, 1997, Hansen, 2006). Initially staff were asked how often they have experienced issues with student teams working effectively in project based learning courses. This was answered on a five point Likert scale with the options always, very often, sometimes, rarely, never. Two open ended questions were then asked:

- What often causes issues within student teams?
- How do you resolve issues within student teams?

Finally with regards to student teams, the staff were asked if they used a team contact for the courses they were involved with.

Based on the responses from the participants, the literature was reviewed in order to compare these finding to others reported. There were a total of 40 potential participants and 20 responses were received giving a response rate of 50%. Of the participants who completed the survey, 55% reported that they were involved in course coordination, 90% involved in teaching and 65% involved in project supervision. Staff demographics were not sought to remove the possibility of identifying staff given the small sample size within one institution.

Results and discussion

Important competencies/capabilities

Staff evaluated a range of different competencies/capabilities in terms of their importance in order to deliver the project based spine courses effectively. A summary of these results is given in Figure 1, ranked from most important to least important. An analysis of the Likert scale questions was conducted. The responses were scored 1-5 (1 not important, 5 being very important) for each question and averaged. The average scores ranged from 4.25 (a willingness to learn and teaching experience) to 2.95 (an understanding of teaching theory).

The most important competencies were a willingness to learn and teaching experience, both receiving the same overall scores. It is interesting to note that while teaching experience rates as one of the most important competencies, an understanding of teaching theory is rated as least important. This is seen as important as it has been reported that fundamental changes in teaching quality and learning are unlikely to happen without teachers changing their conception of teaching (Kember and Kwan, 2000) in a course where teachers become the facilitator (Frank *et al*., 2003) and one of the aims for the redesigned degree was better engagement for students (Tunnicliffe and Brown, 2017). Industry experience (average score of 3.90) and experience managing people and projects (3.85) are seen as moderately important, which is positive since the project courses are industry based and developing the students' teamwork and project management skills, but mildly negative since they are not very important given what the projects are supposed to achieve.

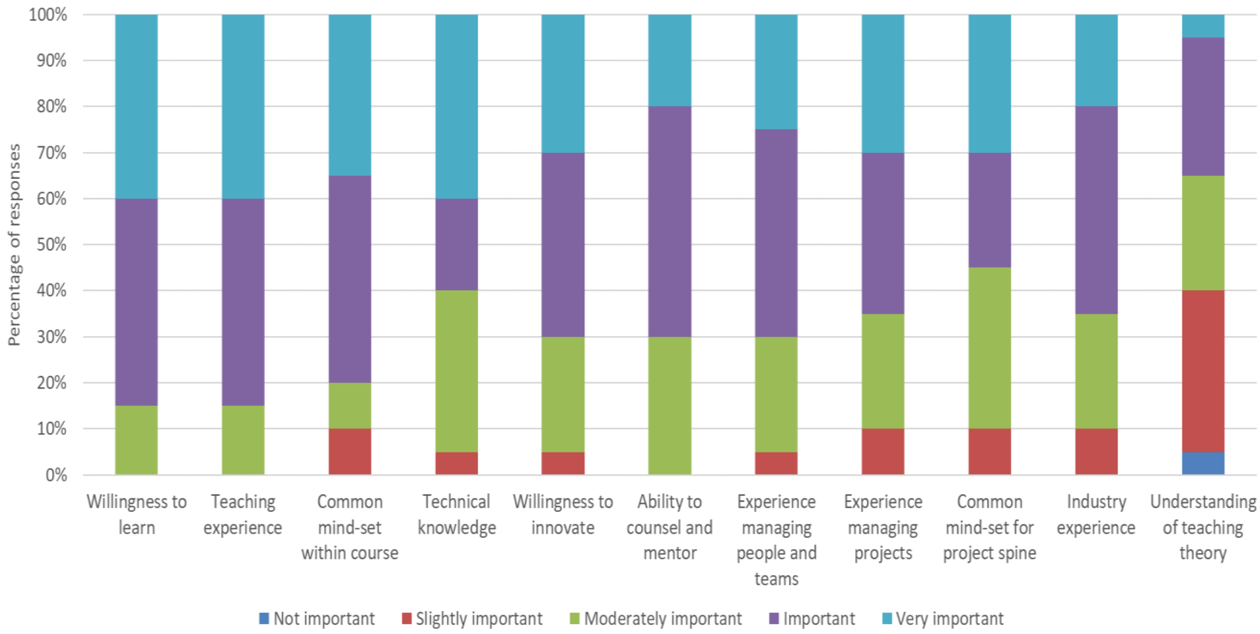

Figure 1: Staff evaluation of the importance of competencies/capabilities for effective delivery of project based courses.

Having a common mind-set within a particular course rated very highly. However staff did not view a common mind-set over the entire project spine as being important. From a student perspective however, this is important to ensure that the skills these courses aim to develop are presented and assessed in a unified way.

Additional competencies/capabilities were also identified in the three areas of motivating/enthusiastic, ability to work with others and flexibility. While the ability to work with others might be linked to 'experience managing people and teams' it appears that the participants saw this as a separate competency as it accounted for 55% of the answers given.

Key challenges when delivering project based courses

Staff were asked the question: What are the key challenges that you have faced when delivering project based spine courses? Using an Affinity diagram analysis each answer was grouped with similar responses and the overall themes together with the frequency of their occurrence are shown in Table 1.They are discussed further below.

Table 1: Key challenges staff have faced when delivering project based courses

Theme	Frequency of response
Group assessment	25%
Different way of teaching	22%
Course organisation/administration	19%
Managing staff	16%
Issues with student teams	13%
Physical resources	6%

Group assessment

As shown in Table 1 challenges with group assessment were identified as the most frequent challenge faced by staff. Assessment is often identified as an issue in the literature (for example Helle *et al*., 2006, Lima *et al*., 2007).

Challenges identified by staff within this theme tended to relate to the challenge of assigning individual marks and peer assessment. For example "marking group reports and allocating marks to individual students" and "peer assessments – who to handle mark allocation as we can be biased". Some courses adopt a web-based peer assessment (Dahm and Anderson, 2013) but this is not used consistently. This is seen as a potential area which needs further improvement, and is a consistent subject of student feedback in course surveys.

Different way of teaching and course organisation

Staff were asked their preferred mode of teaching and the results are shown in Table 2. The 'project day' could be comprised of a mixture of teaching, workshops, project work, meetings with supervisors and assessments. A range of different modes of teaching have been adopted by different courses. For some courses all staff (both teachers and supervisors) attend all classes. The advantage of this mode of teaching is that all staff are familiar with the course content and any instructions given to the students. However this does means that these courses do have a high staff workload compared to a traditionally taught course. Other courses have adopted a split day mode where part of the day will be allocated to teaching and project activities while the rest of the day the supervisors attend and they have project meetings with the students. This mode has a reduced staff workload but there is the potential for confusion due to the students receiving different advice from teaching staff and supervisors. With this mode of teaching clear communication between teaching staff and supervisors is vital.

Table 2: Staff preferences for the mode of teaching

Mode of teaching	Percentage of responses
All staff (teachers and supervisors) present throughout the day	28%
Separate teaching and supervision sessions	44%
A mixture of modes	11%
No preference	17%

Results show that the staff prefer to have separate teaching and supervision sessions compared to all staff being present throughout the day (Table 2). It is thought that because many staff are involved in multiple project based learning courses then the need to dedicate an entire day to each course is probably seen as an issue in terms of managing their workloads, which is consistent with other reported research (for example, Alves *et al*., 2016). Staff had already identified the high workload involved in course management and administration as a key challenge of these project based courses (Table 1). Helle *et al.* (2006), in reviewing many published papers on the implementation of project based learning, reported that the course organisation and administration is often reported as a challenge. Support for administration tends to be underestimated when PBL is implemented (Hung, 2011). The benefits of adopting PBL despite the increased workload can be seen in the increased confidence that students have when assessing their ability in Professional skills (Tunnicliffe and Brown, 2017).

Challenges with student teams

Issues with student teams are often cited in the literature as a challenge associated with project based learning courses (for example Hansen, 2006). Therefore staff were asked how often they had experienced issues with student teams. Results are shown in Figure 2. A wide distribution of answers was given with the most frequent answers being “sometimes” and “very often.”

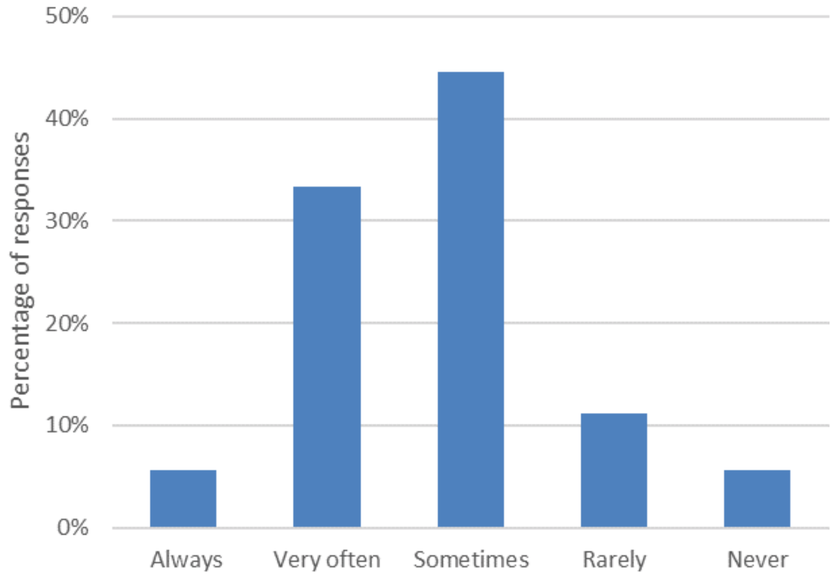

Figure 2: Frequency that staff have experienced issues with student teams in project based courses

Challenges with teams are inevitable as they are known to move through a range of stages which Tuckman (1965) described as forming, storming, norming, and performing. In the ‘storming’ stage discussions can become heated as individuals within the team establish their roles and positions of importance. This can lead to conflict. Hitchcock and Anderson (1997) describe dysfunctional teams as those that get ‘stuck’ in this stage of conflict.

One tool that has been suggested in order to manage student teams is the team contract (Seidel and Godfrey, 2005). This has been adopted by some PBL courses and is set up at the start of the semester by the student teams. It is developed by the team and gives detail of their goals and what they want to accomplish; expectations of team members; policies and procedures; and consequences. Staff were asked whether they used the contract. It was found that 47% of staff had adopted the contract in all courses they were involved with, 29% were not using the contract and 24% were using the contract in some of the courses they were involved in. The team contract is used consistently for the first two years of the programme but thereafter its use varies or is not needed by groups.

Staff were asked to identify what they believed the underlying causes of student team issues were. These responses were grouped by theme and the frequency of these comments is given in Table 3.

Table 3: Causes of team issues according to staff

Theme	Percentage of responses
Student not pulling their weight	32%
Weak student	24%

Theme	Percentage of responses
Cultural differences	14%
Issues with group organisation	14%
Personality clashes	11%
Dominant student	5%

The most common responses were regarding an uneven amount of work being completed by group members either due to students not pulling their weight or a weak student who was not as capable as the rest of the team (Table 3). This is consistent with other research (e.g. Lima *et al*., 2007, Palmer and Hall, 2011). The distribution of these issues by year was not determined. Supervisor meetings, progress meetings and a 'Team Health' check list can help identify issues. Peer Assessment is applied to group marks but it is not effective in helping identify the team issues when used only at the end of the course.

Staff reported that cultural issues led to problems within student teams. In particular the English language level and the tendency for the international students to be shy were identified. International students face many hurdles compared to domestic students. These might include English as a second language (Andrade, 2006; Lethwaite, 1996; Barrett and Huba, 1994), a need for cultural adjustment (Wan *et al*., 2000), a limited amount of ongoing interactions with domestic students (Knight, 1997) and a need to adjust to local teaching and learning styles (Ladd and Ruby, 1999; Stewart, 2007). These challenges can lead to limited participation within the classroom (Tompson and Tompson, 1996). Project based learning can escalate these problems as international students need to work in groups with domestic students. Therefore international students need to work in teams together so that they get the extra support required (Dahm and Anderson, 2013). Ensuring that this done consistently is an area where further improvement is required.

Staff were then asked how they resolved issues within student teams and a summary of the main themes is given in Table 4.

Table 4: Methods used by staff to resolve team issues

Theme	Percentage of responses
Discussion and mediation	71%
Monitoring and early intervention	17%
No solution found	8%
Move student to another group	4%

The vast majority of staff found that discussion and mediation with the team helps to resolve any issues (Table 4). This included individual and group discussions, refering to the team contract, revising plans, and outlining consequences for poor performance. Careful monitoring and early intervention was also found to be useful. Staff suggested that it is important to "identify issues early and make the team confront them".

Only a small number of responses indicated that they had not found a suitable solution. One example given also related to the challenge with international students saying that

> *"I have not found a solution for cultural differences. I have let students resolve issues themselves or grouped students so that it is not a problem."*

Another staff member had found a solution to this stating that

> *"I explain to domestic students that while international students may have limited English and took time to feel confident expressing themselves, they had other skills e.g. maths and could therefore become useful members of the team."*

Conclusions

In this research a staff viewpoint is given regarding the delivery of project based learning courses. In terms of key staff competencies/capabilities needed in order to deliver project based learning courses effectively, a willingness to learn and teaching experience were seen as most important. Of the competencies/capabilities listed, an understanding of teaching theory was viewed as least important. Staff also suggested additional competencies/capabilities and the most common suggestion was the ability to work with others. Given that projects are 'industry-based' the greater importance of teaching experience over project experience can be investigated, as does the greater importance of teaching experience over an understanding of teaching theory, given the change in the way course needs to be delivered using PBL, and the requirement to produce graduates that meet the Washington Accord attributes with respect to professional skills.

In terms of unique challenges with PBL courses, group assessment, the different style of teaching and course organisation and administration were the most common themes. Challenges with student teams did occur on a regular basis but the majority of staff found that discussion and mediation often worked effectively to resolve these issues.

Based on the findings of the survey there are two key areas where staff face challenges which have not been overcome yet. The first of these is the need to generate individual grades from group work and second is the challenges that international students face in project based learning courses. Finally there is a need to apply solutions consistently in each course.

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The use of threshold exams to change students' learning culture and provide assurance of learning

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SELECT SESSION

C1:Integration of theory and practice in the learning and teaching process

CONTEXT

Despite their shortcomings formal examinations are often favoured as a means of achieving learning assurance as students undertake them on their own in a controlled environment. However, while formal exams may mostly ensure the integrity of a student's submission the claim that they provide assurance of learning is less clear. Even if the questions in the exam validly assess the associated subject learning outcomes students are frequently able to pass (achieve 50%) with unsatisfactory, and perhaps even no capacity to demonstrate learning in some subject topic areas, even though they may be regarded as requisite. Furthermore, while undertaking these exams may highlight to students their learning deficiencies, there is often no opportunity for feed-forward assessments to motivate them to address these identified learning gaps. This paper reports on the impact of a threshold exam process on both student learning and assurance of that learning.

PURPOSE

What impact will threshold exams have on the way students behave and respond to the learning outcomes associated with a unit?

APPROACH

A large (>500 enrolments) multidisciplinary first year engineering subject was chosen for this study. Students were required to undertake a threshold exam in week 10 of a 13 week semester. The pass mark was set at 80%. Students who failed this threshold exam were invited to attend a workshop and sit a supplementary threshold exam at the end of the semester. This study used discussion forum posts, student surveys, tutorial discussions and analysis of exam results to investigate how student's behaviour changed as a result of the threshold exam and the impact on their learning.

RESULTS

Despite many students having an objection to an 80% pass rate perceiving it as unfair, the threshold assessments had a significant impact on the way students approached their learning and engaged in their tutorials and other learning activities.

CONCLUSIONS

This study demonstrated the potential of a threshold examination process to improve confidence in assurance of learning. Many student who failed the initial threshold exam focused on mechanical level conceptualisations of learning which suggests long-term changes to their learning culture requires more scaffolding and adoption of such practices in more units of study.

KEYWORDS

Threshold exam, learning motivation, assurance of learning

The use of threshold exams to change students' learning culture and provide assurance of learning

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Introduction

Academics often express concerns about the assurance of learning from assessment tasks. In team based projects and individual assignments these concerns often focus on free riding team members and the possibility of assignment submissions being plagiarised and/or outsourced. Despite their shortcomings formal examinations are often favoured as a means of achieving learning assurance as students undertake them on their own in a controlled environment. However, while formal exams may mostly ensure the integrity of a student's submission (students own work) the claim that they provide assurance of learning is less clear. Even if the questions in the exam validly assess the associated subject learning outcomes students are frequently able to pass (achieve 50%) with unsatisfactory, and perhaps even no capacity to demonstrate learning in some subject topic areas, even though they may be regarded as covering requisite material. Furthermore, while undertaking these exams may highlight to students their learning deficiencies, they have only minor impact on their future learning as there is often no opportunity for feed-forward assessments (apply feedback to subsequent learning and assessment) to motivate them to address these identified learning gaps.

This paper reports on the impact of a threshold exam process on both student learning and assurance of that learning.

Background

Assessment is carried out for many reasons including for quality assurance, ie confirming achievement of learning outcomes, for provision of feedback to students, and for longer-term learning (Boud & Falchikov 2007). Much of the literature on assurance of learning focuses on the program, institutional or national level. While recognising the value in conversations at the institutional level about what we mean by learning standards, we argue, along with Sadler (2009, 2010) and Knight (2006) that the reliability of such learning standards depends on the quality of the assessment in individual units or subjects.

Sadler (2009, 2010) discusses the concept of assessment fidelity, defining this as "...the extent to which elements that contribute to a course grade are correctly identified as academic achievement" (p.728) Sadler (2010) discusses 'effort' and 'attendance' as examples of components of a subject grade that do not provide evidence of learning outcome achievement.

Sadler (2010) and Price et al (2011) also challenge us on the practice of progressive accumulation of marks throughout a semester from tasks set at a lower level than the threshold level for the subject (e.g. simple quizzes). There are two aspects to this issue, one is that marks from these early assessment tasks reflect learning at a lower level than is expected at the end of the subject, the other is that the understanding that students have in earlier stages of the semester may be significantly less than their understanding at the end of the semester. In either case this mark accrual process can "...misrepresent the level of achievement reached at the end of the course" (Sadler, 2010, p.735).

Assessment also provokes an emotional response in students. Boud & Falchikov (2007) report that:

> *".. the emotional experience of being assessed is complex, and is a function of the relationship between the expectations and dispositions of a learner, relationships between learners and other people, the judgements made about learners and the ways in which judgements are made."* (p. 144 ch 11).

Emotional responses are part of everyone's experience of being assessed. For some time, it has been claimed that assessment in general, and examinations in particular, can be very stressful. However, Gabriel and Griffiths (2002) and Palethorpe and Wilson (2011) report that while extreme anxiety disables learning, some degree of anxiety stimulates learning.

Willey and Gardner (2012) present a learning framework that suggests that learning is maximised when an assessment activity provides a well-designed learning opportunity and participants (students) approach the activity with a learning focus. Furthermore, for all assessment activities (both summative and formative) we recommend that academics should use scaffolding to reduce undesirable anxiety, promote engagement and ensure students understand and hence can benefit from the learning opportunity provided. We recommend academics use scaffolding to explain to students:

- why they designed the assessment activity the way they did,
- what learning opportunities the activity provides the students,
- how students can evaluate their learning from the activity, and
- how it is going to impact on their reality (enable them to see the world differently).

Considering these issues our aim in designing a summative examination process was to:

- make it learning oriented and include a feedforward component, allowing students an opportunity to respond to feedback and reassess their learning.
- only provide credit for demonstrated achievement against subject learning outcomes,
- increase assurance of learning in that students were able to demonstrate satisfactory learning in all subject topics, and
- move students to approach the exam with a learning focus.

This paper reports on the impact of a threshold exam process on both student learning and assurance of that learning in a first year engineering subject.

Approach

A large (>500 enrolments) multidisciplinary first year engineering subject was chosen for this study. Students were required to undertake a threshold exam in week 10 of a 13 week semester to demonstrate the subject learning outcomes at a satisfactory level. Students were required to achieve a score of 80% to 'pass' this exam, the aim being for students to have to demonstrate satisfactory understanding in each topic in order to achieve a pass and hence promote assurance of learning. The reasoning being it would be extremely difficult for a student to achieve 80% if they didn't have satisfactory knowledge in all topic areas associated with the subject.

The four scaffolding recommendations previously discussed were clearly articulated to students. They were told that the intent of the exam was for them to have to demonstrate satisfactory knowledge in all requisite subject material; that the exam was learning oriented in that it provided immediate feedback allowing them to identify their strengths and weaknesses and recognise both misconceptions and topics that they may need to revise; and that the requirement to achieve 80% to pass this exam increased our assurance of their capacity to satisfactorily demonstrate the subject learning outcomes. In explaining the requirement to achieve 80% and demonstrate competency it was related to the New South Wales driving test. Like the threshold exam it has a high pass mark (90%) and to pass drivers must demonstrate all the requisite competencies to be given a driving license. This analogy works well as most first year students have received their license within the last 2 years or know peers who have.

Students who failed to achieve 80% in the first exam were given the opportunity to attend a workshop and attempt a supplementary exam in week 14. In the workshops students could ask questions to clarify any misunderstandings and/or address any gaps in their learning. The fact that the exams were marked automatically allowed the instructor to pay particular attention to the most common mistakes in the workshops. These were identified as questions where a significant cohort of students took multiple attempts to achieve the correct answer. The instructor ensured that material addressing these misunderstandings was included in the workshop pre-work. In the week 14 workshop the students work in small groups to compare their pre-work answers before the instructor facilitated discussion on each question, clarifying any misconceptions and subsequently varying the question to check students' understanding.

The time between the first threshold exam and the supplementary exam provided students with the opportunity to revise material addressing gaps in their understanding identified through undertaking the first exam or during the subsequent workshop. This enabled students to feed forward the feedback they received from these activities.

Implementation

The exam was designed to have approximately 3 questions on each of the main subject topic areas. This means with 5 topics there is typically 15 questions. Depending on the number of questions students are typically given between 20 to 25 minutes to complete the exam. The exam is closed book and students are provided with paper on which to write any working out they may need to answer the questions.

The threshold exam consisted of multiple choice multiple attempt (MCMA) questions set at or just above the level of threshold learning outcomes for this first year subject. Students answered this MCMA exam using the Multiple-Choice/Multiple-Attempt mode in SPARK^{PLUS} which allows students to immediately identify if they have answered a question correctly. If they have selected the correct response a tick appears on the computer screen in the relevant square for that option, and the square becomes green. If they selected incorrectly, that response option becomes red and they consider the remaining options, and try again (see Figure 1). Instructors can set up the marking criteria for the exam. In the reported case students were given 100% when answering correctly on the first attempt, 50% when answering correctly on the 2nd attempt, 25% when answering correctly on the 3rd attempt and 0% for answering correctly on the 4th or 5th attempt. This answer and marking summary scheme is shown in Figure 2, and provides feedback for students on their strengths and weaknesses across different topic areas. For the student shown in Figure 2 the strongest areas are Topic 3 and 5 in which the student answered all questions correctly on the first attempt, while their weakest topic area is Topic 1 where they took two attempts to get two questions correct.

This marking regime is fairer than achieved using traditional multiple-choice questions. For example, if a student knows that 3 of the answers are incorrect but is unsure which of the remaining 2 answers is correct then they can achieve 50% of the marks available for the question for demonstrating their partial understanding of the associated topic. Most people can remember leaving an exam and then thinking of the correct answer when it is too late to demonstrate this knowledge nor for it to have an impact on their grade. The MCMA format allows a student who chooses an incorrect answer to be given immediate feedback allowing them to reconsider their thinking and examine the other answers to try and identify where they made a mistake and which answer is correct. Hence, they are learning and getting feedback while undertaking the exam, making MCMA a learning oriented form of assessment that promotes metacognition (students report thinking about their approach to answering questions).

The Multiple-Choice/Multiple-Attempt mode in SPARK[PLUS] was inspired by the Immediate Feedback Assessment Technique (IF-AT) cards. In controlled trials, the IF-AT method was shown to promote both retention of learned material (Epstein et al 2002, Dihoff et al 2004, Brosvic et al 2005, Brosvic & Epstein 2007) and higher levels of independent learning (Brosvic et al 2005; Persky & Pollack 2008). The combination of immediate feedback and the capacity to think about and rework problems that they got wrong at the first attempt assists students in discovering gaps in their knowledge and areas of misconception. Each of these elements has the potential to increase deep learning (Persky & Pollack 2008). Hence if you do not have access to SPARK[PLUS] you could replicate the design discussed in this paper using IF-AT cards (which was the way the authors initially facilitated threshold exams in 2011). SPARK[PLUS] has the advantage of choosing to present the questions to students with the order of both the questions and the answers randomised. This further enhances assessment integrity by reducing the chances of a student being able to gain an advantage by looking at another student's screen during the exam.

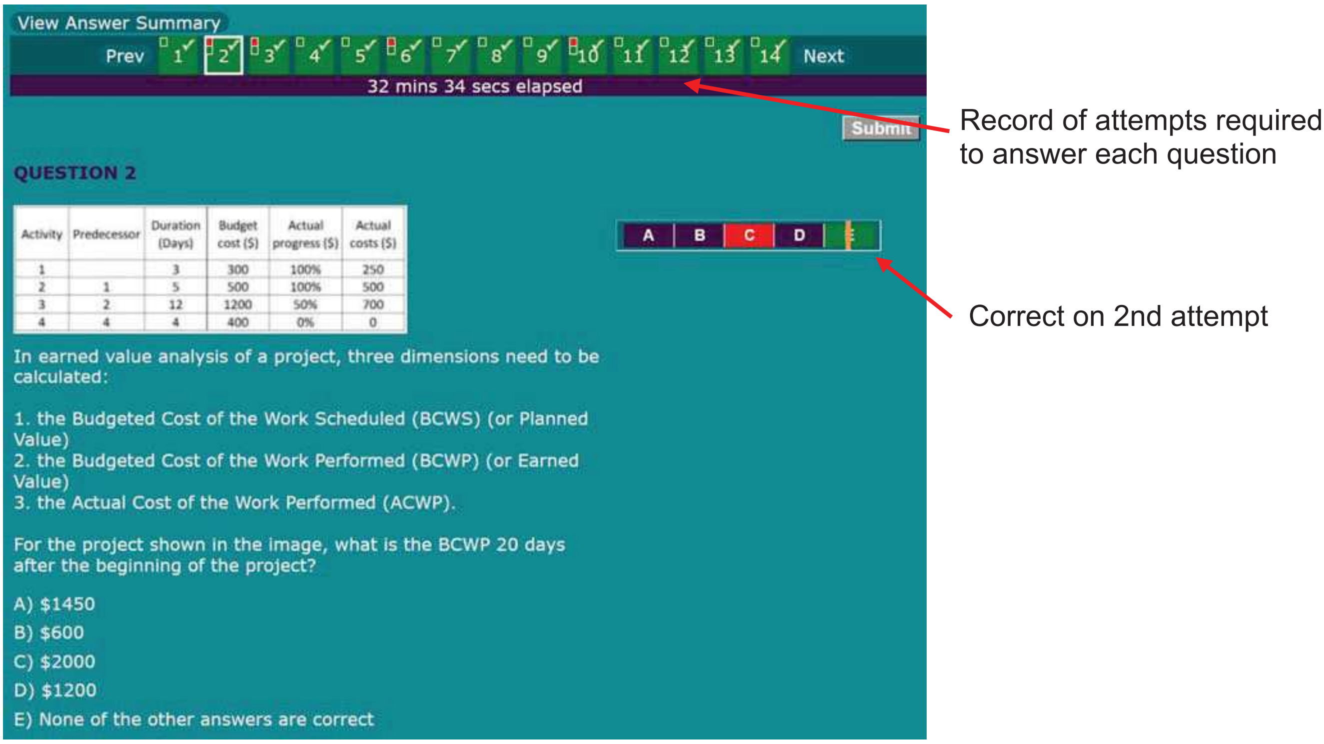

Figure 1: SPARK[PLUS] Multiple-Choice Multiple Attempt (MCMA) assessment screen

While not the focus of this paper SPARK[PLUS] provides analytics for instructors allowing them to identify which questions students had difficulty with, and the frequency with which incorrect answers were chosen and on what attempt. This allows instructors to identify common misconceptions and misunderstandings, as shown in Figure 3. In this case it is showing the cohort's first attempt responses to a question. As you would expect for a questions set at the threshold or satisfactory level most students selected the correct answer on the first attempt while answer C was the most significant distractor. This information is used to provide feedback to students and clarify misunderstanding in subsequent face-to-face sessions. Students are also provided with additional pre-work for the end of semester workshop within which these misunderstandings were further explored and discussed.

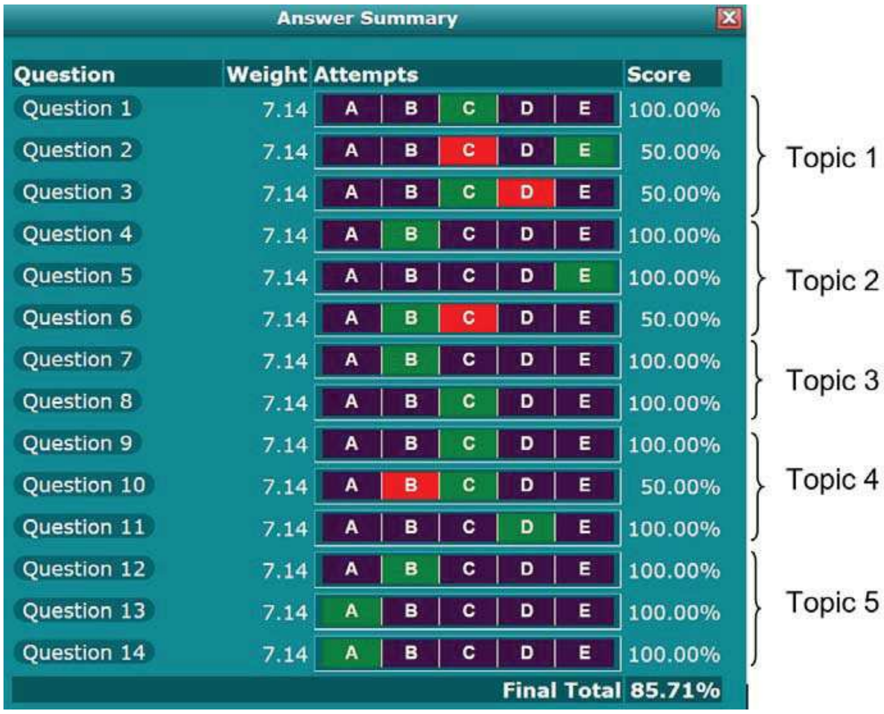

Figure 2: SPARK^PLUS Multiple-Choice Multiple Attempt (MCMA) student answer summary screen

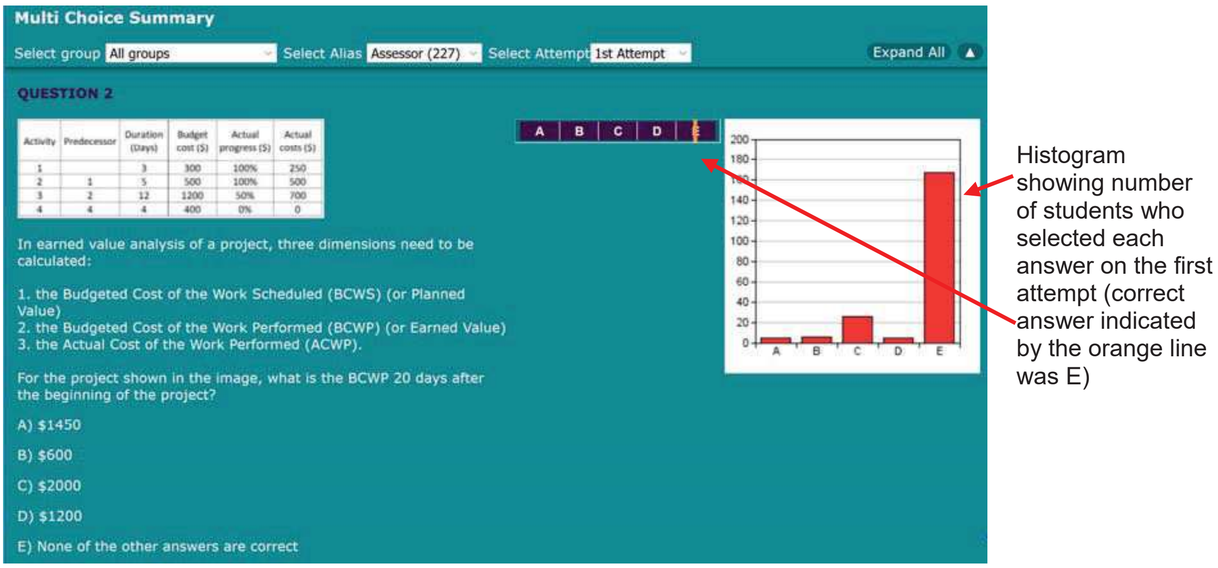

Figure 3: SPARK^PLUS Multiple-Choice Multiple Attempt (MCMA) instructor analytics screen.

In this study discussion forum posts, a student survey, tutorial discussions and analysis of exam results were used as data to investigate how students' behaviour changed because of the threshold exam assessment, and the impact it had on their learning.

Findings / Discussion

A voluntary questionnaire was distributed to students after the threshold exam. Responses were submitted from 203 students of the total 520 enrolled, which represents a 39% response rate. Students were asked to indicate their response on a Likert scale from strongly disagree to strongly agree. The results for a selection of these questions are shown in Table 1 where Strongly Disagree and Disagree responses are aggregated as are the Strongly Agree and Agree responses. These results need to be interpreted keeping in mind the relatively high failure rate (52%) of the first threshold exam and how this may have influenced student's responses.

The results indicate that the threshold exam was successful in motivating students (71%) to engage with the assessed learning outcomes with 64% agreeing that it motivated them to learn all the assessed topics. Students commenting that:

> *Without passing the threshold exam one could not pass the unit and one needed 80 percent to pass it. This motivated everybody to revise very well and work hard but also added a lot of pressure and stress.*
>
> *The threshold exam made me study hard on all the material we have covered in the semester, due to the high pass-mark required. Therefore, I believe this engaged me more with the work and hence I understand everything to a greater degree.*
>
> *Threshold exam pushes me to deeply learn every topic.*
>
> *Failing the whole unit if not passing was the motivation for learning.*
>
> *Since the exam had a pass mark of 80%, it made me study for it and look back at lecture slides and learn the content. Although I thought 80% was a little too high and got my nerves running quite a bit.*

Table 1: Survey results for Threshold Exam

	Strongly Disagree / Disagree (%)	Strongly Agree / Agree (%)
Did the threshold exam motivate you to engage with and learn the material assessed?	29	71
The required 80% pass rate for the threshold exam motivate me to learn all the assessed topics	36	64
The required 80% pass rate caused me to feel stress and anxiety.	15	85
Even though the threshold exam used the multiple-choice multiple attempt format and assessed material at the threshold or satisfactory level required to pass the unit the required 80% pass rate is unfair - it should be less.	23	77

Most students who disagreed that the threshold exam motivated them to learn reported that they are always motivated to learn the material in a subject and hence having a threshold exam had no impact on the way they approached their study or whether they would have studied all of the topic areas:

> *I will learn the material received from lecturer or tutor whatever threshold exam will be held or not.*
>
> *I wanted to get more than 80% anyway so I would have set that pass mark for myself.*
>
> *Nope, 80% or higher would be my goal mark anyway.*
>
> *The required pass rate didn't really motivate me to learn as my approach would have been the same if it was just a normal exam.*

There was much stronger agreement (85%) when students were asked whether the required 80% pass mark caused them to feel stress and anxiety with the majority (77%) agreeing that the pass mark should be less:

> *Yes, because there was such a high pass mark. This caused my peers and I to PANIC AND STRESS an unwarranted amount about the exam.*
>
> *Instead of motivating me to learn and thoroughly understand new material, the 80% pass rate placed more pressure and stress on me.*
>
> *It also caused me to stress out all week and definitely made me feel the worst on the day.*

When asked to suggest a fair pass rate remembering that the exam is designed to test learning outcomes at the threshold or satisfactory level the most common responses suggested between 65% and 70%. A small cohort of students expressed a belief that 50% is a pass mark in any assessment and it is never fair to require students to achieve more to pass.

A less common reason provided by students for the threshold exam causing stress, not associated with the 80% pass mark, included receiving immediate feedback when they selected an incorrect answer. Students mostly liked the multiple-choice multiple attempt format as it gave them a chance to recover from a silly mistake and/or demonstrate their partial understanding of the material assessed on the question even if they got wrong at the first attempt. However, students who were getting many questions wrong reported the immediate feedback increased their anxiety:

> *I mostly felt threshold exam to be stressful when answering the questions and immediately knowing the answer. It really made me nervous during the exam when I saw a lot of mistakes.*

Another stress issue raised by a small cohort of students who believe assessment should always be accumulative felt stressed because passing the threshold exam was a requirement of passing the subject. They felt this requirement was unfair. These students felt that if they passed all of the assignments and group work activities then they should pass the course irrespective of how well they scored in the threshold exam. These students commented that:

> *It seems unfair that the 20% weighted exam can make you fail the entire subject if you fail it.*
>
> *It isn't a good way to learn at all as telling a first year student that they are a failure isn't a great way to start a 4 year degree.*

Several students who failed the initial threshold exam expressed an opinion that the questions were unfair, and it was the unfairness of the questions in the exam rather than their level of knowledge and understanding that prevented them from passing:

> *Most of the questions were vague and ambiguous, as there was not a clear 'right' or 'wrong' answer. The questions could be interpreted in multiple different ways, which was very frustrating as the 'correct' answer was often not how I would interpret a situation. For example, one of the questions was regarding the HOC, and gave a situation where a guard was put in place, eliminating any risk of injury. In the tutorials this was taught as an elimination, however in the threshold exam this answer was incorrect. Even if students like myself put countless hours into study and preparation for this exam, it is very frustrating to find questions that are not based off the content we studied.*

Despite feedback being provided on the first exam and subsequent formative assessment activity it was not uncommon that it was only in the workshop for students who had failed the initial exam that these misunderstanding and knowledge gaps were addressed. The format of pre-work, peer sharing, problem variation and confirmation (Willey and Gardner 2012) was necessary to prevent some students from making the same mistakes again. These problems seem to result when students had a process focused or mechanical approach to learning that favoured learning how to answer a question in a particular context, and then trying to apply the same rules to a different context where the same rules or reasoning could not be applied. This attitude was similar to the attitude reported by Marton, Dall'Alba and Beaty (1993) with “learning as memorizing and reproducing” (p.286). The workshop activities addressed these issues with many of these students volunteering that they now realised they failed the initial threshold exam because of their misunderstanding and knowledge gaps rather than the questions being unfair.

Conclusions

This study demonstrated the potential of a threshold examination process to improve confidence in assurance of learning. Post-exam workshops provided students with an opportunity to first identify and then address their misconceptions before attempting a threshold exam. Student comments show that many of them who initially failed the threshold exam often focused on mechanical level conceptualisations of learning which challenges us to change learning culture.

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Engineers learning about Entrepreneurship: The journey through the lens of an engineering academic.

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CONTEXT In 2016, an innovative course, Startup LaunchLab, delivered by the School of Business, University of the Sunshine Coast, was first offered to engineering students. This innovative course aims to bring an authenticity (the tasks resemble those required in professional life) and proximity (the setting resembles professional contexts) to a work integrated learning (WIL) experience to enhance USC graduates' employability. Embedding experiential entrepreneurship for a multi-disciplinary cohort, which includes engineering students as part of their formal education was a new experience for both the students and engineering academics at USC. The course prepares students to develop a startup in teams, then integrates 'Startup Weekend' as a WIL experience for the students, and asks students to reflect and decide on the next steps to progress their new ventures. This accelerates their learning of what it takes to be an entrepreneur.

PURPOSE The purpose of this project was to develop entrepreneurial skills among a multi-disciplinary cohort of students, required to meet the dynamic labour market challenges, occurring through the combined influences of digital disruption, automation and globalisation.

APPROACH This project evaluates the impact of experiential entrepreneurship on the learning experience and career orientation of a multi-disciplinary cohort of students. In the 2016 offering of the course, the cohort consisted of 24 students across several disciplines (eg. business, journalism, creative industries, education and science), including four mechanical engineering students. A mixed method methodology was employed, collecting survey data before and after the course experience, as well as interviewing students three months after course completion. In 2017 eight engineering students who were enrolled in the fourth-year Reservoir and Stormwater Course participated in the Startup Weekend as one of their assignments.

RESULTS The 2016 quantitative data collected showed students experienced significant attitudinal changes related to their entrepreneurial intentions, entrepreneurial self-efficacy and practical steps to start a new venture,. The interview data, analysed thematically, showed engineering students realised the value of leveraging multi-disciplinary skills and collaborating with business, and design students as well as the importance of being customer focused when developing solutions, which forms the basis of a new venture. Finally students highlighted the importance of taking an experimental approach to test assumptions regarding their new venture, and confirm assumptions or pivot (adapt) when discovering their assumptions were incorrect.

CONCLUSIONS Engineering students who collaborate with team members, who have complimentary skills, are able to progress their startups quickly, and these venture team members are useful in articulating the value proposition of the startup to non-technical audiences. The Startup LaunchLab course is particularly useful to develop entrepreneurial skills as graduate attributes. This is critical given that engineers are known globally to have engineering skills to develop high potential ventures, with the prospect to become job creators.

KEYWORDS Entrepreneur, Experiential learning

Introduction

Since the early 2000's recognition has grown that entrepreneurial skills are increasingly required by engineers (Creed *et al.*, 2002). Dynamic labour market challenges occurring through the combined influences of digital disruption, automation and globalisation drive this trend. In response to these influences, an innovative course, Startup LaunchLab, delivered by the School of Business, University of the Sunshine Coast, was first offered to engineering students in 2016. This course aims to bring an authenticity (the tasks resemble those required in professional life) and proximity (the setting resembles professional contexts) to a work integrated learning (WIL) experience to enhance USC graduates' employability. This course builds on previous offerings that used a Multidisciplinary Experiential Entrepreneurship Model (MEEM) (Barnes and de Villiers Scheepers, 2017).

Embedding experiential entrepreneurship for a multi-disciplinary cohort, including engineering students as part of their formal education was a new experience for both engineering students and academics at USC. The course prepares students to develop a startup, then integrates 'Startup Weekend' as a WIL experience for the students, and asks them to reflect and take the next steps to progress their new ventures. This accelerates their learning of what it takes to be an entrepreneur. This paper presents the results of the Startup LaunchLab trial of 2016, which attempted to develop entrepreneurial skills among a multi-disciplinary cohort of students, which included engineering students.

Background

This project evaluates the impact of experiential entrepreneurship on the learning experience and career orientation for the multi-disciplinary cohort of students. To undertake this evaluation a mixed method methodology was employed, collecting survey data before and after the course experience, as well as interviewing students three months after course completion. During the Startup Weekend, research observers took notes at regular intervals of all the startup teams, which had formed. These observations were collected using a structured process allowing comparison across different observers. The survey instrument was constructed to measure entrepreneurial intention (Linan and Chen, 2009), self-efficacy of the students (Cassar and Friedman, 2009), learning orientation (De Clercq *et al.*, 2012), resilience and entrepreneurial persistence (Baum and Locke, 2004) and the students' passion for entrepreneurship (Cardon *et al.*, 2013).

Results

Over two years (2016-17) a total of 36 students were enrolled in the Startup LaunchLab course, which focuses on new venture establishment (**Figure 1**). In the 2016 offering the cohort consisted of 24 students across multiple disciplines (eg. business, journalism, creative industries, education and science), including four mechanical engineering students. The course was offered to all mechanical engineering students as an elective several months prior to the start of the semester. Some difficulties with approving the students to undertake the course were encountered as it was limited to those students who had not already done the two electives available to them. This resulted in only four engineering students enrolling in the course.

The 2017 offering of the entrepreneurial course failed to attract any engineering students and a different approach was adopted. The fourth-year reservoir and stormwater engineering course (ENG411), which had eight students undertaking the environment and water major of the civil engineering degree, were offered the opportunity to participate in the startup weekend to fulfil the requirements of one of their assignments.

In 2017, at the time of the Startup Weekend the ENG411 students were studying reservoir sedimentation. A novel method to measure sedimentation using temperature arrays was suggested by the lecturer and this was used as the basis of the 'product' developed for the weekend. This approach required the students to learn about the sedimentation process, the extent of the problem, mitigation and remediation measures and the organisations responsible for its management. This informed the development of a business model and focus on the market; a completely new experience for the engineering students.

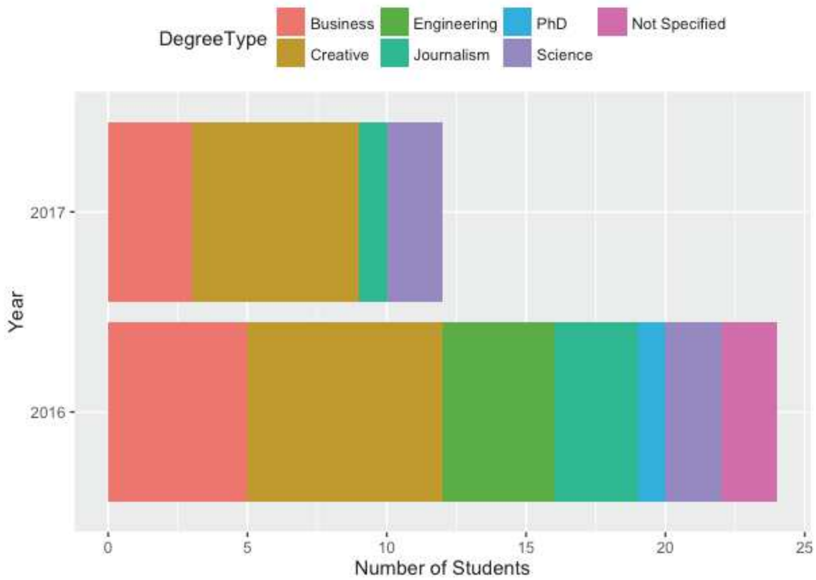


Figure 1: Breakdown of student participation in ENT311 over 2016-17 by degrees

The 2017 group of engineers formed one team. In addition to the ENG411 students, several other students from the mechanical engineering discipline heard about the weekend and offered their services in return for entry to the event. Several engineering lecturers were also registered and they attended at various times over the weekend.

The challenges faced by the participating engineering students differed to those of the 2017 cohort because of their model of participation. In 2016 the Engineering students involvement were prepared for the startup experience through the course, however in 2017 the students who attended, focused mainly on their assignment. For the 2017 group, one of the observers noted the development of a great team who all appeared dedicated and bright. Though their product was identified as having potential, the observer noted that the team had no idea of startup or entrepreneurship terminology or how to construct a business model. It was evident team members hadn't talked to 'customers' and maintained a big product focus throughout the weekend. They were also observed to be very task focused and despite the large size of the team had successfully divided tasks among team members.

Team conflict developed over the weekend between the students who were doing the assignment and the volunteer mechanical engineering students. This was due to the direction the mechanical engineering students wanted to take the project. The mechanical engineering students did not return to the event on Sunday, however they were very helpful on the Saturday providing soldering assistance and instruction to the civil engineering degree students. There was a rift within the civil engineering student cohort on the Sunday with one of the students leaving the project and consequently withdrawing from the course.

The engineering students who participated in the 2016 Startup Weekend were part of the entrepreneurship course, multi-disciplinary cohort and developed a deeper understanding of the entrepreneurship, business, market development and the startup ecosystem concepts. . There were only four students enrolled in this course and they were all required to pitch an idea at the Startup Weekend as part of their assessment. The pitched idea did not have to be based on their engineering skills specifically, and they were free to recruit team members from other disciplines.

Survey data

To analyse 2016 survey data, the Science and Engineering students were grouped together and all other students assigned to "Other" (Business and Arts students). Entrepreneurial intent was measured by asking four questions around future career goals and business intentions. The survey results prior to the startup experience revealed that Science and Engineering students were more inclined to consider entrepreneurship as a career goal, compared to Business and Arts students, though do not appear to be as serious about setting up their own business in the near or longer term. **(Figure 2).**

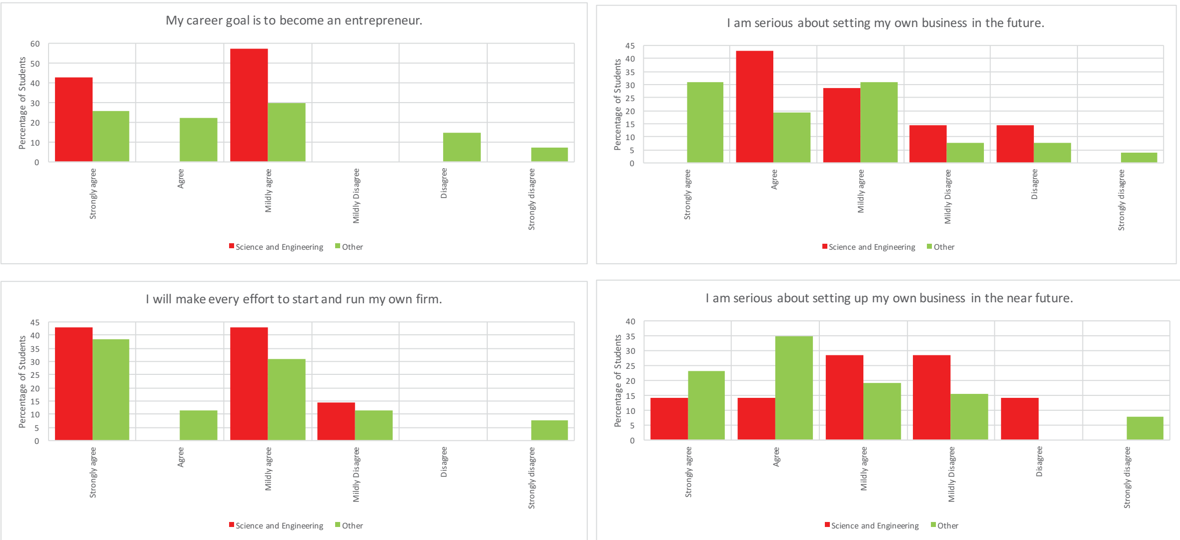


Figure 2. Responses to questions relating to entrepreneurial intent prior to the startup event.

Four questions were asked in the survey to measure the student's self-efficacy. Prior to the startup event experience, most Science and Engineering students were confident of their abilities to start and run their own business or creatively solve problems. This contrasted to a small percentage of the Business and Arts students who were less confident in relation to these two questions (Figure 3).

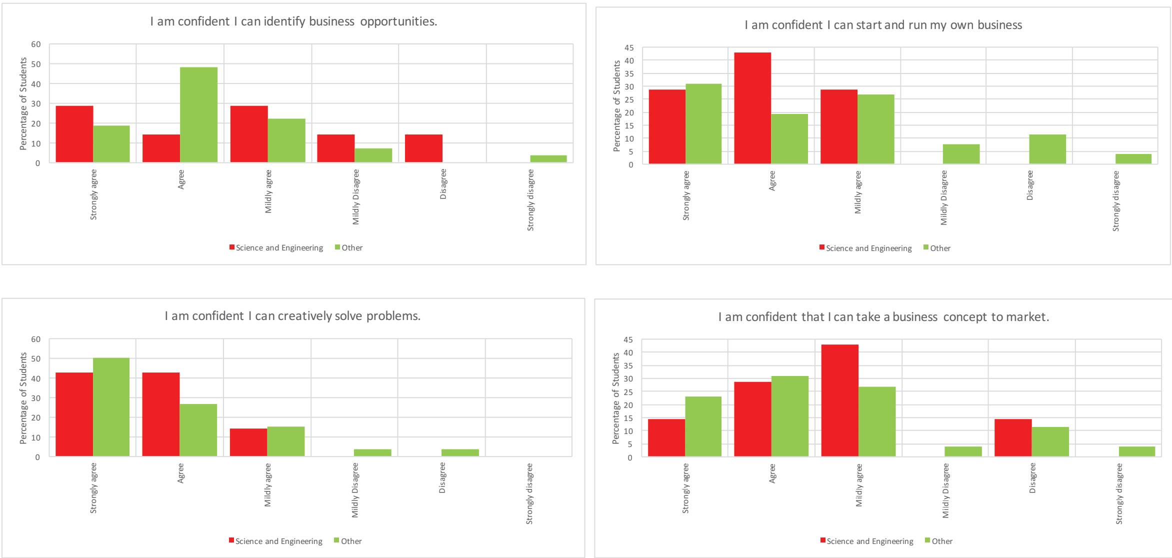
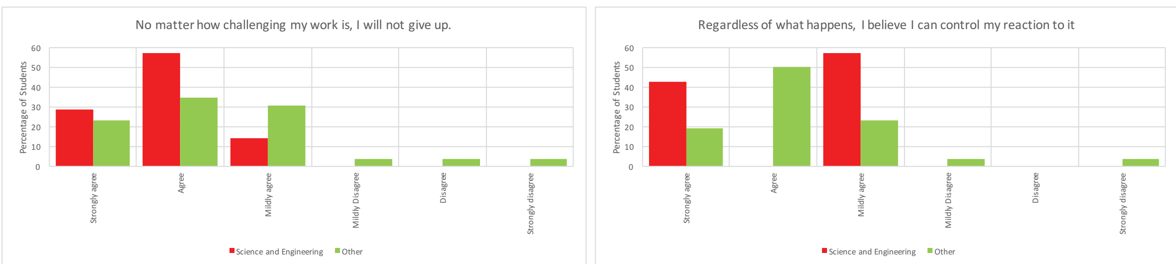


Figure 3. Responses to questions relating to student's self-efficacy prior to the startup event.

In response to learning orientation, the Science and Engineering students agreed to some extent to the three questions asked. There were only a very few 'other' students who disagreed to any extent to these questions (Figure 4).

Figure 4. Responses to questions relating to student's learning orientation prior to the startup event.

Four questions were asked to measure the students' resilience and entrepreneurial persistence. The answers to these questions showed the clearest difference between the Science and Engineering students and the Business and Arts students. The Science and Engineering students agreed to some extent to all of the questions, compared the Business and Arts students responses (Figure 5).



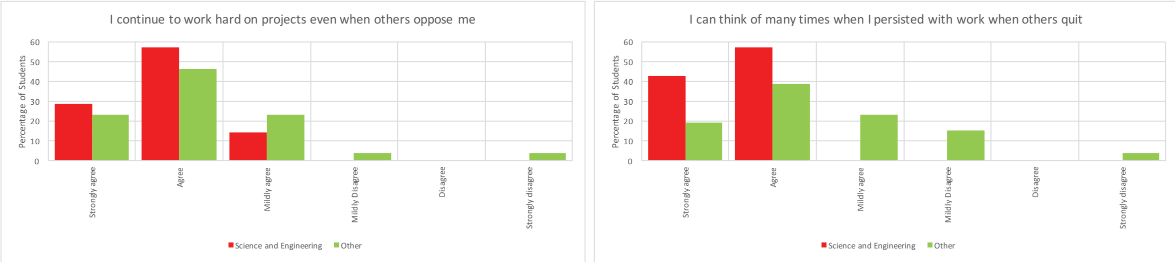


Figure 5. Responses to questions relating to student's Resilience and Entrepreneurial persistence prior to the startup event.

Quantitative data collected prior to 2016 showed students experienced significant attitudinal changes related to their entrepreneurial intentions, entrepreneurial self-efficacy and practical steps to start a new venture (data not shown). There were insufficient survey responses to measure attitudinal changes from the 2016 and 2017 cohorts.

The interview data, analysed thematically, showed engineering students realised the value of leveraging multi-disciplinary skills and collaborating with business, and design students as well as the importance of being customer focused when developing solutions, which forms the basis of a new venture. Finally, students highlighted the importance of taking an experimental approach to test assumptions regarding their new venture, and confirm assumptions or pivot (adapt) when discovering their assumptions were incorrect.

Conclusions

Engineering students who collaborate with team members, who have complimentary skills, are able to progress their startups quickly, and these venture team members are useful in articulating the value proposition of the startup to non-technical audiences. The Startup LaunchLab course is particularly useful to develop entrepreneurial skills as a graduate attribute. This is critical given that engineers are known globally to have engineering skills to develop high potential ventures, with the prospect to become job creators. It is recommended that engineering students join students from other disciplines and prepare for this type of intensive, authentic startup experience. This will enable them to learn the relevant concepts and processes, and facilitate their progress, so that they not only focus on product development, but also market and business model development. Incorporating entrepreneurship courses into a demanding engineering curriculum.

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Visualising Student Satisfaction

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CONTEXT
Student satisfaction is an important metric used in teaching and education, and is used in most educational institutions. There are many ways to measure student satisfaction (Elliott, 2002), however student satisfaction is often given as both a numerical score on a Likert scale as well as a text comment which contains further information. Although the numerical scores are often used, the free text comment is an invaluable source of information, often providing further pointers towards possible teaching enhancements.

PURPOSE
In this study, we explore the use of machine learning techniques to visualise student satisfaction. This visualisation will be exploited in the context of the following 2 research questions,

1. How can we use visual representations of comments to examine student satisfaction?
2. What impact can this have for educators?

APPROACH
Using a dataset of over 20 subjects, many student comments and reviews were available for analysis. Primarily, using an analysis method called Latent Dirichlet Allocation (LDA) (Blei, et al., 2003), topics can be extracted from these comments about subjects. Sentiment analysis is then used to find the positivity and negatively of certain comments.

RESULTS
Using the approach mentioned, comments from two subjects were analysed to demonstrate the capability of the process. For each subject, two figures were generated, one about the subject, and one focussing on a keyword or topic of interest. Both figures contain 9 automatically determined keywords as the focus of the plot. For each keyword, the length of the bar represents the frequency of keywords. The positive and negative sentiment is also represented on the same figure. From these figures, the reader can identify keywords related to a particular positive or negative sentiment.

CONCLUSIONS
In this work, we have shown a process which automatically analyses and produces a visual representation for student satisfaction. The produced visuals can be used by lecturers, subject coordinators or managers to compare and review several subjects at once. As a lecturer, you would not need to know how this system works, but have access to student feedback. With the student feedback, these plots can be automatically generated. The visualisations can lead to quick detection of both positive and negative aspects within a subject, thus prompting appropriate action.

KEYWORDS
Sentiment Analysis, Student Satisfaction, Machine Learning, Student Surveys

Introduction

Student feedback is very important for improving teaching practice and allowing students to express their views and ideas. Part of a teacher's role is to manage and address the expectations of students, and feedback and ratings from evaluation allows that to be done (Cheong Cheng, 1997). From feedback, pointers and information can be determined and hopefully influence the teaching style and method of delivery.

One form of feedback is determining whether the student had a positive, negative or neutral experience in a subject. Sentiment analysis is a method which aims to determine this positive, negative or neutral sentiment of a text statement. Many of these surveys ask for a rating on a Likert scale, which will show sentiment, but this number does not provide information about the sentiment of important components mentioned within a response. For example, a response may say "The lectures were informative. The tutorials were difficult". With a single rating or number, we can't determine which teaching activity students were satisfied or not satisfied with.

In this work, we explore some text analysis techniques to automatically analyse student responses. The main technique used here, known as Latent Dirichlet Allocation (LDA), allows a document to be classified into several topics, and each topic represented by some keywords (Blei, et al., 2003). This is an important initial step for producing a visualisation of student satisfaction.

Research Questions

In this study, we explore the use of machine learning techniques to visualise student satisfaction. We aim to develop a method which will improve on existing techniques used for visualisation, allowing the produced figures to be generated with an education use as the primary objective. This visualisation will be exploited in the context of the following 2 research questions,

1. How can we use visual representations of comments to examine student satisfaction?
2. What impact can this have for educators?

Motivation

Being able to visualise a student's perception of a topic or perception of a subject of interest is very powerful. Quite often lecturers and universities have access to a large number of responses from students and being able to easily summarise these would be useful in a number of applications. As an example, in the Reframe framework (QUT, 2015) students are asked to rate their overall satisfaction with the subject, and provide a free text comment. These satisfaction scores are often used to compare subjects and assess student satisfaction, but student satisfaction ratings can be flawed and may not be accurate. For the student perception of subjects to be examined properly, all the text comments need to be read. With large subjects, this can be quite time consuming for a lecturer to read through the comments and summarise the key points. If a Dean or manager is trying to assess multiple subjects, reading through all the comments is an almost impossible task, and there is no easy way to compare two subjects together. In this work, we develop a visualisation method for students' text comments, and compare our results to the outputs of two existing text analysis software.

Method

The Data Set

Introduced in a previous work (Cunningham-Nelson, Baktashmotlagh, & Boles, 2016) we use a dataset consisting of over 20 subjects across four years. QUT runs two student surveys titled 'Pulse' and 'Insight' (QUT, 2015) obtaining students' feedback in the early weeks of the semester and at the end of semester. In each of these surveys, students are asked to rate their views on three statements. They respond to each of these questions on a 5 point Likert scale. For this work, we are focusing on the final statement "I am satisfied with this unit so far" in both surveys. An open-ended response is then presented to the students, allowing them to give feedback or further information on the scores that they give. This feedback often contains suggestions for teaching improvements which can be used by teaching staff for future iterations of the subject. An example of one of these responses is,

Satisfaction rating: 5. "Great structured unit. Very well organised and great learning environments"

This shows a satisfaction score, and a comment which seems to reflect the student's satisfaction in the subject. This however is not always the case. The comment below shows an example where this is not necessarily the case,

Satisfaction rating: 3. "Way too much new information all at once, which is then built on the very next week, whether we have a solid foundation or not…"

This satisfaction score given shows that the student is ok with the subject, but this is not really reflected in the comment. It is important that we consider both the satisfaction scores as well as the comments given by the students.

Choosing a Subset of Data

The total data set consists of many subjects, across many semesters, and the two surveys. Depending on the desired purpose, the data can be used wholly, limited to a faculty, subject, semester, etc. The data chosen depends on the type of level of information the user wants. For analysis in this paper, the data used has been limited to single subjects within a single semester. Both the "Pulse" and "Insight" survey data was used.

Pre-Processing the Data

When text data is being analysed, it is important to pre-process it, to ensure that small inconsistencies don't have a large effect on the results. For this analysis, several actions were performed on the data, including,

- Changing the text to be all in lowercase, so that "Hello" is treated in the same manner as "hello".
- Removing the stop words (i.e. the, and, a) which are present in these responses, as these are not important for the overall meaning.
- Lemmatising the words (using the base of each word). For example "running" would become "run" for the purposes of analysis.

Determining Keywords

After cleaning and preparing the data, methods which could then determine keywords were investigated. One obvious method to determine keywords would be to use a frequency count to see the words which are mentioned most frequently. This however does not group words of similar topics together, and would perhaps include words that are not necessarily keywords. Using the LDA method previously mentioned (Blei, et al., 2003), we can split the document into a set number of topics, and this will group similar terms under one keyword. The implementation and testing of this was performed in Python. In this study, we have selected 9 keywords, and run the LDA methods 10 times as the keywords returned can be slightly different each time. The most common 9 keywords are selected as the keywords to represent the subject.

Finding Sentiment of a Response

After the keywords have been selected, the sentiment of each keyword is determined. Sentiment refers to the positivity or negativity of a word. Common examples where sentiment analysis can be used are movie reviews (Jong, 2011) or product ratings. Twitter data is often used a sample dataset to train and test sentiment analysis models (Pak & Paroubek, 2010).

When finding the sentiment in this work, the responses are initially broken into individual sentences, to isolate each idea. Using a dataset known as “AFINN” (Nielsen, 2011) we can see the sentiment of individual words. AFINN has a list of words which have been rated with an integer between positive and negative 5, depending on satisfaction. For example, the word “amazing” is labelled as a *+4*, and the word “conflict” is labelled as a *-2*. The sentiment of each word is added up across the sentence, to give an indication of the students satisfaction. If the overall score is negative, the sentiment is deemed to be negative, and if the score is positive, then the sentiment is also positive. The sentiment calculated is then linked with the keywords that occur within a sentence. The sentiment and keywords are then combined into a figure, together with frequency of occurrence. This provides an initial view of the subject overall.

Focussed Keyword Feedback

Taking this further, we can narrow down the data used to include only responses with one keyword within the selected unit. We can then search for additional keywords, which are mentioned often in conjunction with the keyword of interest. This is used as an additional visual, to give more information into reasons why a keyword may have a positive or negative sentiment.

Results

The analysis techniques described above can be used to identify subject overall feedback or feedback specific to a keyword. As a use case, two subjects in single semesters were selected to visualise student perception by using keyword specific data and identifying positive and negative sentiment.

Example 1

For the first example, two plots show an overall view of the subject, automatically identifying keywords within all the students’ responses, as well as the associated sentiment with that keyword. The first subject selected was a first-year engineering subject that had free text comments given by 72 students. These comments can range from positive to negative, providing suggestions and allowing students to express how they felt about the subject. Figure 1 below shows a whole subject level analysis of these responses.

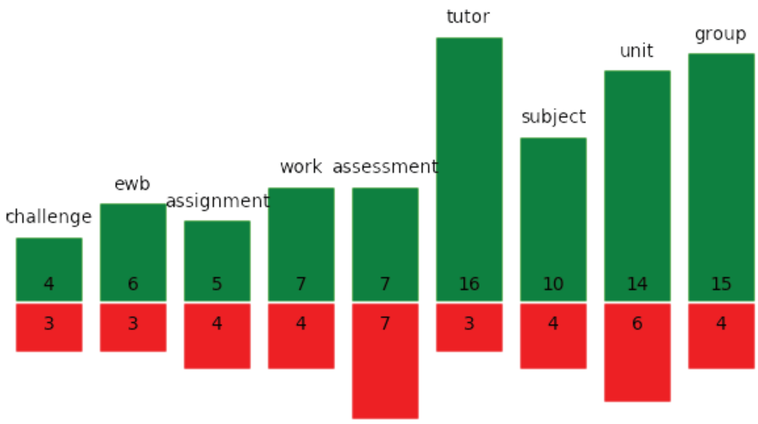

Figure 1 – Example 1: Single Subject Analysis

In this graph, nine keywords have been extracted, which are nine "topics". These topics summarise the text corpus. Let's focus in on the keyword "tutor" as an example. From this visual representation, we can see that 16 people mentioned tutor in a positive sense, and 3 negatively. This makes a total of 19 responses using the keyword tutor in either a positive or negative sentiment. We can conclude from this representation, that most students are content with tutorials. If desired, we could examine the negative responses for further detail.

Looking again at the graph above, we can see that the keyword "assessment" has equal positive and negative sentiments. This makes it an important keyword that we might want to focus more on. Figure 2 below shows a focussed analysis of responses which contained "assessment".

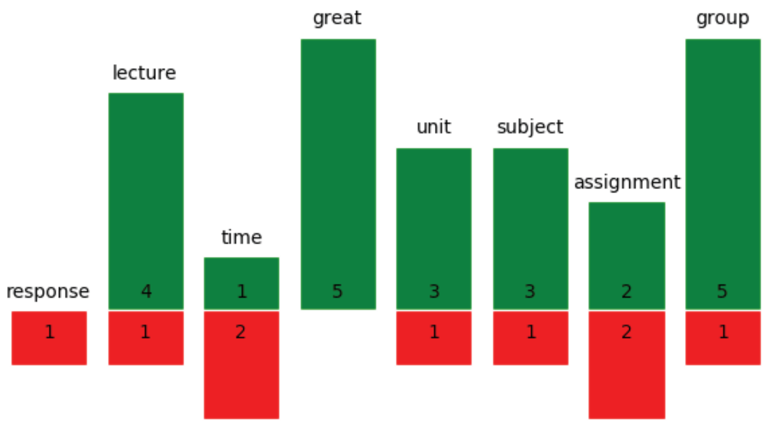

Figure 2 - Example 1: Focussed Keyword Analysis

From this graph we can see keywords (topics) that students are mentioning in the same responses that mention assessment. It is important to note that in this situation, most students use the words unit and subject interchangeable. Looking at the keyword "group" first as an example. This suggests that most people are happy with group components of the subject, and possibly the group components of "assessment". A part of one of the student's comments which also reflects this is shown below,

> *"… manageable load of work but would not have wanted anymore assessment. Also happy with the way the load is split so that if there is trouble with groups you can still have the chance to pass if you put the work in..."*

Figure 2 also shows that some students negative feeling associated with the word "time". One response which reflects this is below, *“'Mixed response from assessments. Good insight into today's problems but waste of time”*

Example 2

Let’s consider another example of a different subject. This is a second-year engineering subject. Figure 3 below again shows another 9 automatically obtained keywords for this subject. We invite the reader here to stop and think about the possible conclusions that could be drawn from this information. Figure 4 is included also, giving a focussed keyword analysis for the word “lecture”, for further consideration.

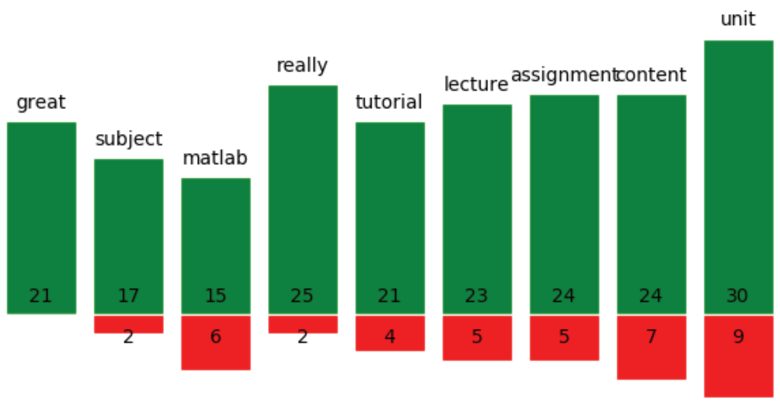

Figure 3 - Example 2: Single Subject Analysis

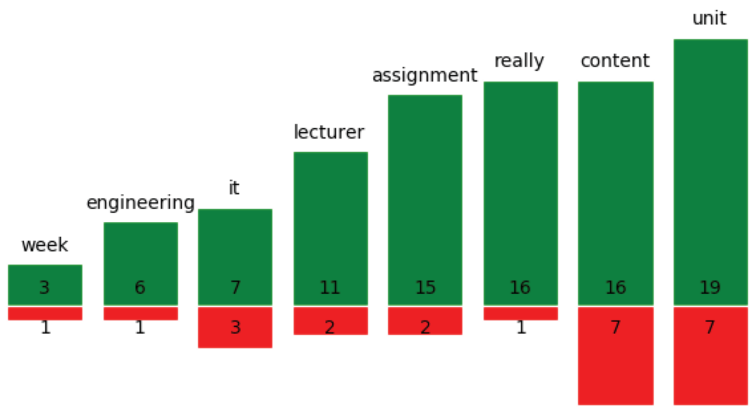

Figure 4 - Example 2: Focussed Keyword Analysis

Examining Figure 3 above, we can see that students have a positive outlook on most aspects of the subject. Keywords such as “matlab” were found to be key terms in responses for the subject, and the programming language MATLAB was taught in the subject. Analysing Figure 4 further shows some keywords commonly used in responses with lecture. For example, “lecturer” is mentioned mostly in a positive light. This is reflected in the comment below,

“It's great to have such a passionate and inspiring lecturer…”

Content might be an area which we could examine and investigate more closely. Again, selecting a comment, we can see this reflected below,

“Main Lecture: Sometimes hard to understand what he is saying, would prefer if all the content was contained in the slides…”

These visualisation techniques are able to inform the decisions which we make about teaching strategies or which comments we may want to read more closely, without reading the entire set of comments. This is quite powerful, especially when dealing with a large number of comments.

Comparison with other Visualisation Techniques

Other text visualisation software is available; and we have selected two pieces of software to demonstrate some capabilities and limitations with current visualisation tools. Leximancer and a Word Cloud generator are discussed and shown below. The capabilities of each piece of software are presented, and compared against the solution presented in this study. The same dataset used in Example 1 is used for a consistent comparison.

Leximancer

Leximancer (Smith & Humphreys, 2006) can analyse a given text input. Leximancer has many options. It allows the user to pick a number of topics, and also allows the user to combine terms and topics. Figure 5 shows an example of an output which Leximancer can produce from the “example 1” data. The figure shows relationships between words, for example “group” and “work” are linked closely, as they were often mentioned together in the context of group work.

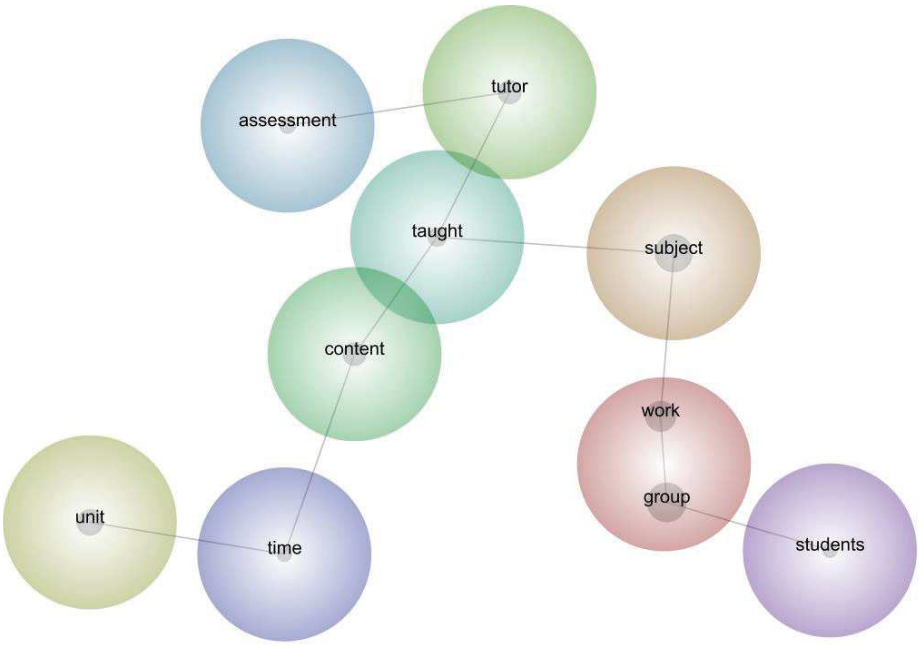

Figure 5 - Leximancer Diagram for Example 1

Leximancer however has several limitations when it comes to visualising student satisfaction. Firstly, a knowledge of the software is required to generate this type of plot, as well as a software license. Some manual labelling and grouping is required to generate these plots. The plot is also lacking in information about the frequency of occurrences, as well as sentiment information for student satisfaction. You can find frequency information, but it is not represented on the same plot.

Word Cloud

Word Clouds are another commonly used tool for visualising text. They are available to use for free and require very little knowledge of the platform to use. The cloud conveys the key words and frequencies, the more commonly occurring words being represented larger. This allows important words to be brought to the reader’s attention easily.

The word cloud is lacking in several of the same aspects of the Leximancer representation for this application. Sentiment is not conveyed, and some important aspects can sometimes become hidden amongst the other words.

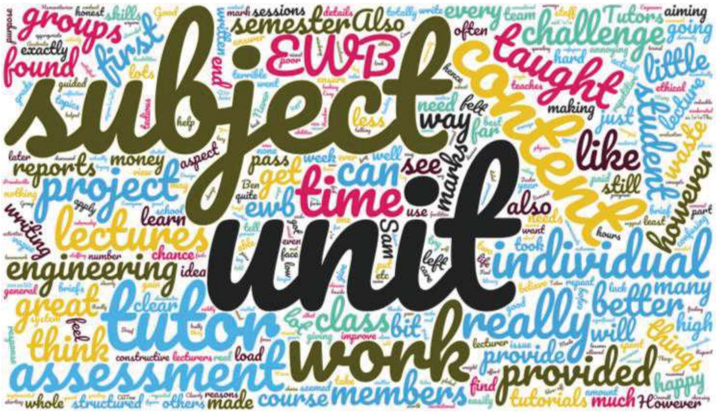

Figure 6 - Word Cloud for Example 1

Conclusions and Recommendations

In this paper, we present a consistent way to automatically analyse and produce a visual representation of student satisfaction for a subject. This can be useful when a reader is dealing with a large number of comments, or would like to compare two subjects together visually. In these visualisations, keywords are extracted automatically and grouped into topics which are most relevant to students, as conveyed in their responses. The sentiment is then found for each of these selected keywords, meaning that the reader can examine the proportion of comments which mention the selected keyword in a positive or negative light. The responses can then be examined even further, selecting a keyword to investigate further, and finding which other keywords are mentioned often in conjunction with the selected keyword. This allows for patterns and enable possible improvements in selecting and implementing teaching strategies to be extracted, helping both educators and students.

It is important to emphasise that the entire process for creating the figures is automated, apart from the user selecting a keyword which they want for the second stage of further analysis. This is quite powerful, as it allows scalability for any number of comments, and larger comments sets may provide more insights. Future work includes looking at additional ways in which sentiment can be found, using a scale as opposed to a singular positive or negative result. Being able to improve how the keywords or entities are detected, as well as investigating possible links between these words would help to strengthen this work.

Being able to visualise student satisfaction from comments and feedback is a powerful tool. The produced visuals can be used by lecturers, subject coordinators or managers to compare and review several subjects at once. As a lecturer, you would not need to know how this system works, but have access to student feedback. The lecturer also has the option of changing more detailed parameters based on their needs. With the student feedback, these plots can be automatically generated. The visualisations can lead to quick detection of both positive and negative aspects within a subject, thus prompting appropriate action.

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The fundamentals are important…but what are they?

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SESSION C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

CONTEXT The development of an engineering practice degree in which students learn entirely through industry projects has decoupled the curriculum, where curriculum is considered to be the comprehensive list of skills, content and achievement standards that students must achieve as they progress through their degree, from the unit-based structure of the course. This means that rather than taking a series of units such as 'calculus' and 'thermodynamics', students learn the fundamental maths, physics and engineering concepts when they become relevant in the context of a project. However there are still certain bodies of knowledge and skills that all students must master if they are to work as engineers and it is crucial that 'the fundamentals' are learnt by all students regardless of the specific projects that they work on. A hierarchical learning structure is also still essential, as students must master certain basic concepts before progressing to more complex ideas, but the paths through this new structure will be more fluid, and different for each student depending on the projects they undertake, their particular roles in each group project, and their personal learning goals.

PURPOSE To identify what the key fundamental knowledge is that all graduate engineers must have mastered to become engineers capable to contribute in 21st century practice.

APPROACH Several approaches are being used to identify the fundamentals. The first is to consult the industry partners who are co-designing and co-delivering the practice-based course. They have been very clear about the broad skills they require from graduates and can provide insight into what knowledge is essential and assumed for students entering their practice. The second is to map current engineering curricula, looking at the core knowledge blocks and with an emphasis on the flow through the topics. If a particular topic is required for a project, the previous mastered knowledge must be identified and student attainment tracked to ensure students have sufficient grounding to access the content and apply it in the project context. This mapping process will also identify which areas currently taught do not lead into any other topics are not required for projects or used in industry.

RESULTS Digital disruption and a rapidly changing world have rendered many traditional techniques unnecessary while necessitating the development of many other skill and knowledge sets by engineering students, and it is not yet clear exactly what these will be. It is anticipated that while some knowledge is perpetually fundamental, much of what is traditionally taught may no longer be relevant to modern and future practices of engineering.

CONCLUSIONS Early consultation with industry partners indicates a greater focus on budgeting and financial maths is important, along with a greater emphasis on mathematical modelling and programming skills. 'Basic' maths and physics are considered fundamental but more detailed research is needed to identify specific key topics areas.

KEYWORDS Fundamental knowledge, practice-based learning.

Introduction

Changes in society and technology have radically altered 21st century engineering practice and graduate engineers increasingly require different skills and knowledge to be employable. However engineering courses, while attempting to make headway in addressing the need for the development of key transferable skills such as communication, have not changed in terms of fundamental content for a number of years. This raises a number of questions such as has the fundamental knowledge required of engineers changed? What do engineers still need to understand and be able to calculate from first principles and what has been replaced by technology? Do we need to teach how to use software tools and if yes, which ones? Do all engineering graduates need the same technical depth in fields or is there scope to produce different kinds of engineers, some with technical depth, others with a broader background?

One of the greatest criticisms of traditional engineering pedagogy is that it is a theory based science model that does not prepare students for the 'practice of engineering' (Felder, Woods, Stice, & Rugarcia, 2000). In most engineering courses it is traditional that in first year engineering, the majority of student time is spent on the mathematical and scientific basics that underpin all engineering disciplines. In the second and third year, students may work on industry and/or community projects, and industry practice takes place in the final year (Jawitz, Shay, & Moore, 2002; Ku & Goh, 2010; Webster, 2000) or as a work placement during the course. In a course based entirely around projects the course must be defined and structured to allow students to obtain the required fundamental knowledge. Previous research studies suggest that engineers should experience a broad base of fundamental knowledge, skills, and engineering applications in practice within an undergraduate course and later develop their specialist skills through professional practice in their selected discipline (Lima, Carvalho, Assunção Flores, & Van Hattum-Janssen, 2007).

To address these issues a practice-based approach has been developed in which students work in teams on industry-set projects from day one of their course and throughout, with all content being taught in the context of these projects. The curriculum is being co-designed with industry partners through consultation process ensuring it is relevant to current engineering practices (Cook, 2017), a process adapted from the "Design your Discipline (DYD)" stakeholder consultation process created to facilitate curriculum renewal in undergraduate programs (Dowling & Hadgraft, 2013). The practice-based approach is designed to motivate future engineers by establishing relevance in using the fundamentals at appropriate places where it is needed in industry projects from day one of their course, as establishing relevance is one of the main factors which induces students to adopt a deep learning approach (Ramsden & Entwistle, 1981).

The development of an engineering practice degree in which students learn entirely through industry projects has decoupled the curriculum, where curriculum is considered to be the comprehensive list of skills, content and achievement standards that student must achieve as they progress through their degree, from the unit-based structure of the course. This means that rather than taking a hierarchical set of units such as 'calculus' and 'thermodynamics', students learn the fundamental maths, physics and engineering concepts as they become relevant in projects. Obviously a hierarchical learning structure is still essential, as students must master certain basic concepts before progressing to more complex ideas, but the paths through this structure will be more fluid, and different for each student depending on the projects they undertake, their particular roles in each group project, and their personal learning goals. While this is laudable in terms of allowing students to have individual learning journeys, there are still certain bodies of knowledge and skills that all students must master if they are to work as engineers, the 'fundamentals'.

In the context of a new practice-based engineering degree, in which students learn entirely in projects, when curriculum is decoupled from unit structure in this way, core knowledge must be carefully mapped and student attainment tracked. However the new structure of a practice-based course allows many assumptions to be challenged, including exactly what is the fundamentals knowledge required to be an engineer is in the 21st century, both for all engineers and for specific disciplines.

Previous work examining the different skills engineers require in 21st century practice has focussed on determining the generic competencies, with many authors calling for increased recognition of skills such as teamwork and communication, business and enterprise skills and generic engineering competencies around digital literacy. Methods used to determine which competencies are necessary in 21st century engineering are many and varied, spanning literature reviews (Male, 2010), stakeholder consultations (Spinks, Silburn, & Birchall, 2007), surveys and focus groups (Male, Bush, & Chapman, 2011), interviews (van der Wal, Bakker, & Drijvers, 2017) and observations (Cardella, 2008).

Work around the fundamental knowledge required by engineers has often focused on mathematical and digital skills. The universal use of ICT in all sectors changes the nature of the mathematical and technical skills required in the workplace, but does not reduce the need for mathematics (Hoyles, Wolf, Molyneux-Hodgson, & Kent, 2002). Niss (2003) identified eight mathematical competencies, where competency is defined as the ability to understand, judge, do, and use mathematics in a variety of contexts and situations. The competencies identified are: thinking mathematically, reasoning mathematically, problem posing and solving, modelling mathematically, representing mathematically, communicating mathematically, symbolism and formalism language, and using aids and tools. Firouzian (2016) surveyed students, teaching academics and practicing engineers about the perceived importance of Niss's eight mathematical competencies and found a mismatch in the perceptions of academics and practicing engineers. Mathematical modelling was most important to both groups but practicing engineers rated the importance on using tools and software far more highly than academics.

This result agrees with the findings of van der Wal et al. (2017) who use the terminology techo-mathematical literacies as coined by Kent, Bakker, Hoyles, and Noss (2005) to describe the combinations of mathematical, statistical and technological skills necessary for successful performance in the workplace. They used semi-structured interviews of fourteen engineers from a spectrum of technical engineering domains to determine seven main categories of techo-mathematical literacies: data literacy, technical software skills, technical communication skills, sense of error, sense of number, technical creativity and technical drawing skills.

This intersection between mathematical understanding and application and 'using tools and aids' is where what is considered fundamental knowledge is shifting. As one of the participants in van der Wal's study says "I have to say, calculus and such, I have never used it. Most of the time it is hidden in the software, and it would be nonsense to let someone calculate for a whole day what a computer can do in a minute." There are many questions to be answered around what fundamental knowledge is needed in this new technology-driven world where information can be accessed at the touch of a finger and digital tools are ubiquitous.

This paper outlines the start of the process of identifying just what these fundamentals are as they apply to 21st century engineering practice.

Approaches

To identify what the fundamental knowledge is a variety of approaches have been considered. The first approach is the top-down stakeholder consultation approach, which has used the industry consultation framework described in Cook (2017) to develop the broader curriculum for this degree to understand the knowledge, skills and mind-sets industry partners employing graduate engineers are seeking. The second is from the ground up, examining the current topics taught in the first year of an undergraduate engineering degree and seeing how these map to the outcomes required by industry, identifying any branches that do not connect in either direction.

The industry consultation process included a series of ideas workshops, curriculum consultations and deep dive workshops centred around the course pillars of social impact, emerging technologies, research & development and entrepreneurship.

The purpose of the ideas workshops was to explain the practice degree concept to Industry, get their initial feedback and ask what knowledge, skills and mindsets they would like graduate engineers to enter their industry already possessing. The outcomes from the ideas workshops was a list of skills and attributes that was organised into a framework which was presented back to Industry partners in the curriculum development workshops where is was built-out and adapted. This early consultation with industry partners indicated a greater focus was required on business and enterprise skills, that budgeting and financial maths are important, along with a greater emphasis on mathematical modelling and analysis of big data.

The curriculum deep-dive workshops then looked in detail at the curriculum areas connected to the four pillars of the course: social impact, emerging technologies, research & development and entrepreneurship. In these workshops participants were asked to expand on specific curriculum points, what they meant in their industry context and what skills and experiences student engineers would need to be able to demonstrate mastery of these. The content taught in the core units of the current engineering degrees were mapped to produce detailed content trees, indicating the topics taught, the interdependencies of the topics and the pre-requisite knowledge for each topic.

At the time of writing the process of deep-dive industry consultation is ongoing, with some preliminary results presented here.

Results

The process of industry consultation in still ongoing but some key ideas have emerged from the stakeholder consultation process. Some general themes that have emerged from industry workshops suggest an increased focus is required on professional skills, business and finance, understanding organisational values and culture and valuing sustainability and environmental issues (which are not considered further in this paper), coding, data analysis and mathematical modelling. Automation, AI, 3D printing and design were also emphasised as being important broad areas student engineers should be exposed to. Specific areas within these were discussed in the workshops and from these the fundamental knowledge underpinning them mapped out.

The result of the mapping process is a complicated web of topics, with many interdependencies. An example of the outcome from the curriculum mapping is provided in Figure 1. In unpacking the automation area identified in the Emerging Technologies industry workshop, an outcome was that graduates should have the ability to use, select and control actuators. This graduate outcome was linked (by the curriculum development team) to different types of actuators, such as electrical, mechanical, hydraulic and pneumatic actuators. For the purposes of this paper, results are limited to mapping curriculum associated with mechanical and electrical actuators only. The operating principles for electric actuators are also linked to mechanical actuator principles (e.g. gears and drives. The control of these two actuator types was mapped to principles of fluid statics and dynamics for hydraulic actuators, and principles of electromagnetism for electric actuators). Underpinning these engineering principles are the fundamental mathematical and scientific principles and concepts. For the use and control of actuators, the identified fundamentals included basic algebraic expression, differentiation and integration, principles of force, energy and work, substance properties, and measurement (including units).

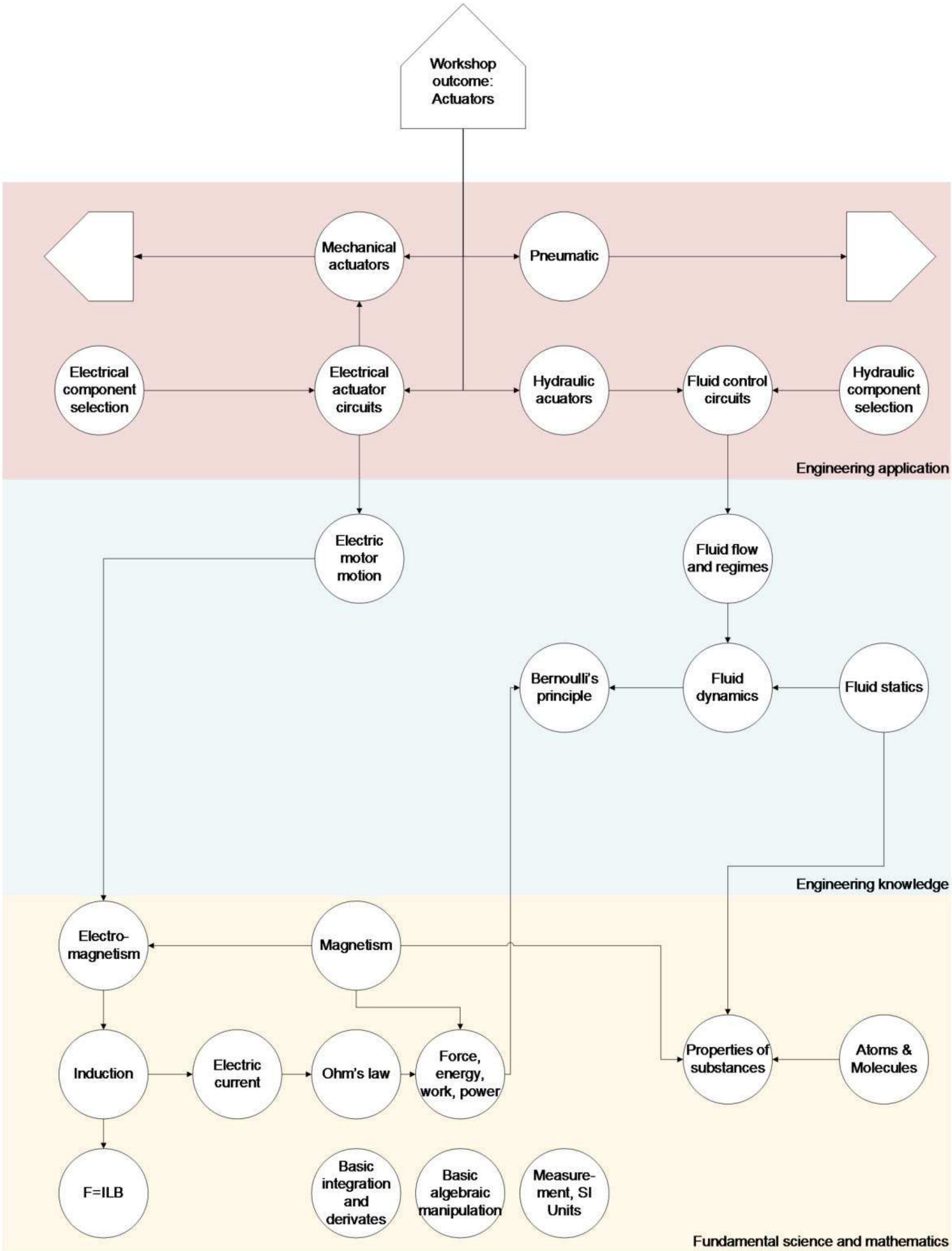

Figure 1. Example of identified linkages between industry outcomes, engineering principles and fundamental science and mathematics for actuators.

The linkages from the engineering principles converged to shared mathematical and scientific principles; these are considered to be the fundamentals. It is expected that further mapping of the top level industry outcomes to engineering principles will identify further shared mathematical and scientific principles. In addition, it is anticipated that many of the fundamentals delivered within traditional engineering curriculum may not be mapped, suggesting that they do not need to be included in the core curriculum. However, these excluded fundamentals may be required within the curriculum for specialist engineering fields, depending on specific industry outcomes.

Discussion & Conclusions

It is apparent that while, in a traditional education system, students are contained to a well-defined convergent problems, industry expects creative and innovative academic practice that provides students valuable practical knowledge. Students require an opportunity to apply engineering knowledge in practice, which means the purpose of engineering education in most cases is to graduate engineers who can demonstrate engineering application in real world scenarios (EA, 2012).

This model of using stakeholder consultation has highlighted broad concepts that are required by engineers and here it has been used to attempt to identify the fundamentals underpinning those concepts in terms of basic of mathematics, physics, electrical energy, electronics circuit theory, environmental and materials science, mechanical design, telecommunication networking, coding and programming etc. In all workshops there was a strong focus in the discussion on the importance of generic competencies such as communication and teamwork, skills as suggested by others (e.g. Male (2010)), often making it challenging to elicit responses from industry participants focussing on more technical competencies.

This process of identifying concepts and unpacking them to determine the key knowledge that underpins them is an involved process, requiring iterative consultations with stakeholders and in-depth mapping of interdependent topics at a detailed level. This work is ongoing. Digital disruption and a rapidly changing world have rendered many traditional techniques unnecessary while necessitating the development of many other skill and knowledge sets by engineering students, and it is not yet clear exactly what these will be. It is anticipated that while some knowledge is perpetually fundamental, much of what is traditionally taught may no longer be relevant to modern and future practices of engineering.

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In-Class and Asynchronous Student Response Systems: A Comparison of Student Participation and Perceived Effectiveness

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CONTEXT: Student response systems (SRSs) are effective tools to enhance interactive learning in large lecture settings by making learning interesting and engaging with the use of a technology students are familiar with (Preszler et al., 2007). Furthermore, in-class SRSs provide instant feedback to students on their learning, reducing the need for teachers to engage outside of class (Walvoord and Anderson, 1998). However, learning happens in many forms and occurs as a result of students engaging in activities inside and outside the classroom (Astin, 1993; Pascarella and Terenzini, 1991). This study explores the effectiveness of learning activities using SRSs to enhance non-engineering student engagement and to support their learning in an engineering module of a general education course. To our knowledge, this is the first time that a comparative study on the effectiveness of in-class versus asynchronous SRSs based on student participation and their perceived effectiveness has been conducted.

PURPOSE: We hypothesise that SRSs can enhance student engagement and learning in engineering classrooms to better enable non-engineering students to learn about engineering concepts in a general education first year course on sustainability.

APPROACH: Quizzes, consisting of seven questions each and based on the assigned reading and learning material covered in the previous class, were administered in every engineering class through Google Forms (synchronous activities). In addition, online practice questions were created in our learning management system, Canvas, so that students were able to participate anytime from anywhere (asynchronous activities). At the mid-point of the course, a summative student evaluation about the effectiveness of the SRSs was conducted using an online questionnaire in Qualtrics. The survey explored the student perception on enhanced engagement and improved learning outcomes in an engineering module of a general education first-year course (N = 110) which included five other modules.

RESULTS: Forty eight out of 110 students (44%) completed the questionnaire to measure the effectiveness of the SRS. About three-quarters of the students strongly agreed and agreed that SRSs were helpful for their learning, increased their engagement with the course and would recommend extending the use of similar SRSs to other course modules, not just the engineering one. Overall, 75% of the respondents also believed that SRS increased their interest in engineering and improved their learning in this module of the course. Students expressed a preference for SRS tools embedded in Canvas over the use of Google Forms.

CONCLUSIONS: The results demonstrate the effectiveness of SRSs in enhancing non-engineering students' learning experience by improving their engagement in an engineering classroom. What is clearly evident from the student perception is that the use of SRSs, both in-class and asynchronous, is highly recommended for courses that require students to engage in a significant amount of assigned readings that is beyond students' main area of study and in cohorts with wide-ranging academic backgrounds as was the case for this general education course.

KEYWORDS: Student response systems, asynchronous, online quizzes, active classroom

Context

Teaching engineering concepts to a general education audience at undergraduate level is especially challenging as the student cohort is essentially non-engineering focused. The current study was conducted in a first year general education course at the University of Auckland. The purpose of this course is to introduce students to the theory, science, and practice of sustainability. The complex and dynamic nature of sustainability is illustrated in this course through a multi-disciplinary approach, addressing the roles and implications of social and cultural practices (sociology module), legal framework (law module), current governance, economic and business models (business module), planning, design and management of the built environment (planning module), basic science that underpins sustainability (science module), and product and technology manufacturing and life cycles (engineering module).

Typical class sizes for this general education course range from 100-150 students. This course is team-taught whereby lecturers from various disciplines (Engineering, Arts, Business, Law, Science, and Planning) contribute to the course in their respective modules. The engineering module comprises four weeks of lectures and tutorials (three weeks before and one week after the mid-semester break) while the other five Faculties split the remaining 8 weeks of the course into their discipline-specific modules. Last year (2016) was the first time the lead author taught this course, and while experiencing some positive feedback at the time, there was a considerable room for improvement as was evident through student feedback received, either through students' comments or through student course evaluations. In addition, many students didn't read the assigned course materials uploaded through the learning management system (LMS), Canvas.

The goal of this study was to improve student engagement and evoke interest in an engineering module on sustainability in a general education course comprising mainly non-engineering students. It was hoped to improve engagement not just in the classroom but also online through the implementation of student response systems (SRSs) to foster active learning.

Introduction

To be an effective teacher in engineering seems challenging to many academics as there seems to be a disconnect between 'getting through content' and 'ideals of teaching'. This presents significant challenges when incorporating active learning to reduce the transmission style of lecturing. Constructivism taken too far can dilute the rigour needed in STEM subjects (Felder, 2012). By contrast, rigour taken too far can be stifling and disengaging. Hence, there is a need to rethink traditional engineering pedagogical practices to help students learn in an exciting environment without compromising on the rigour that is necessary for the engineering education.

One of the conventional methods for engaging students in the classroom has been through textbooks and external readings. Course instructors assign readings to students for a variety of reasons, most commonly because it is often impossible to present all recommended course material during class time (Ryan, 2006). Completion of assigned readings before a topic is covered in class allows students to better comprehend the class material, and in turn, increases in-class participation and student interactions (Ryan, 2006; Gurung, 2003; Narloch et al., 2006; Appleton et al., 2006).

However, student compliance with reading assignments has steadily declined over time (Clump et al., 2004; Sappington et al., 2002; Burchfield and Sappington, 2000). There can be a variety of reasons for this decline, including increased presence of electronic gadgets and the distractions they can create in students' academic lives (Gilbert and Fister, 2011). Nathan (2005) links low levels of reading comprehension to a student's desire for more personal time. A National Endowment for the Arts report (2007) reinforces the hypothesis that students spend significantly more time on media and electronic devices than on reading (Hoeft, 2012). Rather than banning these gadgets and technology from the classroom it is worth exploring whether these can be used for the benefit of student learning instead.

New techniques to increase student reading and class participation for a better understanding of the assigned course material are constantly trialled (Gibbs and Jenkins, 1992; Novak et al., 1999). One such technique is assessing students learning through frequent quizzes on reading assignments (Narloch et al., 2006; Angus and Watson, 2009). Having regular in-class quizzes can encourage students to pay closer attention to the assigned reading material as well as the course content, which can improve their understanding not only of the reading material, but also of the lecture material presented in class (Narloch et al., 2006; Brothen and Wambach, 2001; Graham, 1999) resulting in increased student engagement as defined by Axelson and Flick (2011). In addition, frequent quizzes may lead students to study regularly during the semester rather than cramming just before the final exam (Narloch et al., 2006; Clump et al., 2004; Gilbert and Fister, 2011).

However, it is reported that although scheduled or surprise in-class quizzes can motivate students to complete the assigned reading, students tend to view such quizzes as punishment depending on how those are administered (Sappington et al., 2002; Graham, 1999). Hence, it is important to administer quizzes optimally and integrate with other learning activities for a holistic course design rather than quizzes being an add-on and met with resistance by students.

A variety of ways to administer online quizzes (in-class and asynchronous) exist and different methods may vary in effectiveness. For example, the use of randomly administered quizzes may result in higher levels of reading compliance (Ruscio, 2001), and selection of subsets of questions from large question banks can reduce the likelihood that students will simply memorize response options without learning the material (Daniel and Broida, 2004).

Furthermore, research suggests that presenting feedback separately, after the student answers each question, including both information about accuracy and a source of additional information, can enhance the learning experience for students (Ryan, 2006; Brothen and Wambach, 2004). Pedagogical research findings also suggest that online in-class quizzes for assigned readings can provide students with a variety of positive learning outcomes (Hillman, 2012; Salas-Morera et al, 2012). For example, the use of online administered quizzes has been shown to motivate students to complete assigned readings, increase participation in class discussion, and improve performance on exams for material covered both on the quizzes and in class (Brothen and Wambach, 2004; Johnson and Kiviniemi, 2009).

The question 'do regular online assessments enhance student-learning outcomes?' is still the subject of considerable debate in the literature. Bonham et al. (2003) and Engelbrecht and Harding (2004) noted that online assessments (as compared to manually marked paper-based assessments) resulted in no discernable difference in student performances over a range of summative assessments. Likewise, Smith (2007) found that online quiz scores showed higher correlation with final examination marks than laboratory or assignment marks. Grimstad and Grabe (2004) found that students who completed voluntary quizzes significantly improved their exam performances. However, their conclusions were explained by good students being both motivated to take voluntary quizzes and likely to do well on examinations. Brothen and Wambach (2001) cautioned that mandatory quizzes only improve exam performance if students employ an efficient strategy of using the quizzes to test their own knowledge of the material, rather than attempting to use the quiz to learn the material.

Kibble's (2007) study of a large cohort (n ~ 350) of Medical Physiology course demonstrated the effect of varying the incentives given to students to complete online quizzes. Kibble summarised results under three key findings: first, students who elected to use online quizzes performed better in summative examinations; second, when the incentives were increased, student participation rose dramatically; and third, quiz scores were significantly correlated with final examination results. Similarly, Angus and Watson (2009) found support for the hypothesis that regular usage of online learning tools significantly and positively contributed to student performance.

Overall, much of the literature suggests an improvement in learning outcomes when online quizzes were used as low-mark formative (or summative) assessment involving medium to large cohorts (greater than 100 students). However, more data and studies will be valuable in this domain. The lack of research with respect to the use of frequent formative assessments for engineering classrooms comprising mainly non-engineering students provides the opportunity to fill that research gap. No single research project can possibly examine all facets of this complex relationship between learning interventions and student learning, but the focus can be on developing a greater understanding of one element without denying the existence of the others (Fry et al. 2009, Kahu, 2013). Therefore, the focus of this study is to explore the student perception on the use of frequent formative assessment through the use of online quizzes in the classroom, i.e. learning together (synchronous), and outside the classroom (asynchronous).

One method of administering effective online formative assessments is through the use of in-class SRSs (Preszler et al., 2007). An SRS is a form of technology that offers teachers the opportunity to ask students in the classroom multiple-choice questions to which they reply individually by selecting an answer. This was traditionally conducted through a hand-held wireless transmitter, called ‘Clickers’. Students choose their answers by using Clickers that send a signal to a receiver attached to the teacher’s computer, and the results are displayed for the entire class to see. However, Clickers are usually expensive to obtain for large classes. With the advent of new digital technologies, their use is also becoming obsolete.

Moreover, digital, mobile technologies are increasingly making their way into the classroom such as SRSs that use Google forms or online polling or quiz software (Mathiasen, 2015). Mathiasen (2015) states that SRSs play an important role in assessing student progress and capturing the type of learner data that allows teachers to understand their students’ progress and intervene in a timely manner, often feedback can be immediate after students completed the task. It makes learning interesting, and engages students with a technology they are familiar with in an interactive learning format (Preszler et al., 2007). Based on the literature (Padhye, 2016), not only the feedback on the accuracy of student selected answers but providing sources of additional information can enhance the student learning.

Objective

This study aims to design, apply, and evaluate effective online quizzes as a part of SRSs to enhance student learning in a general education course that teaches engineering concepts to mainly non-engineering students.

Methodology

The SRSs were implemented as two components. Five in-class quizzes (in Canvas) were administered for every engineering class after the first week of lectures. These quizzes consisted of six multiple choice questions each, plus a discussion-oriented question for which there was no correct answer. The open-ended question, based on the overall theme of the lecture, was used to record student responses and generate in-class student discussion regarding the topic. Since participation in such in-class SRS relies on student attendance and the intention was to reach all students enrolled in the course, an asynchronous component to the SRS was also offered whereby new online quizzes were created so students could participate in this activity anytime from anywhere. Literature shows that providing such flexibility in administering quizzes is essential to increasing student participation and engagement (Sappington et al., 2002; Graham, 1999). Both SRSs, asynchronous and synchronous, were trialled as voluntary student self-assessments and were therefore not marked as part of the overall grade. The student perception on the effectiveness of the SRSs for their learning was collected via an online questionnaire comprising eight questions.

In-Class Online Quizzes (synchronous)

The design of in-class online quizzes was informed by the literature and by formative assessment models (McSweeney & Weiss, 2003; Smith, 2007; Stillson & Alsup, 2003). The quizzes were written with the third-party software, Google Forms. Google Forms were selected based on their versatility, availability, and student familiarity (Gehringer, 2010; Haddad and Kalaani, 2014). Many universities are using Google Apps for Education. Google forms can serve as an effective tool for SRSs, providing a wide range of response formats that extends beyond traditional clicker options. Students are provided with instant feedback for their answers, immediately after each quiz, and are given credit for the number of questions they answer, or the number of correct answers they submit over the course of the engineering module. Previous work has shown that giving credits increases the response rate for online quizzes (Gehringer, 2010) even though these quizzes are not part of the course assessments.

Overall, five in-class quizzes were administered during five engineering classes. All quizzes comprised seven questions each. Students were advised before the class started to bring in an electronic device, capable of accessing the internet. Links for the quizzes in Google Forms were displayed during class for students to access. Ten minutes were dedicated in each of five classes for students to complete the quizzes and for in-class discussion of upcoming questions relevant to the topic.

Online Quizzes in Canvas (asynchronous)

In parallel with in-class SRS, online quizzes were created in Canvas as an asynchronous SRS. A total of 31 multiple choice questions that were different from in-class quiz questions were created based on the lecture content and assigned reading material of the engineering module. The link for students to access those were posted each week on the course webpage and remained active for the entire time of the engineering module before the semester break when it was closed. The purpose of creating another form of SRS was two-fold: first, to capture students who do not attend classes and thus missed participating in synchronous SRSs, and second, to compare students' preference of one form of the SRS over the other.

Questionnaire

After the six weeks of the course, which included three weeks of the engineering module and the other three weeks of science and sociology, a summative evaluation for measuring the effectiveness of the SRSs was conducted using an online questionnaire in Qualtrics during the seventh week of the course. This study received approval from our university's Human Participants Ethics Committee (reference 018673). Student consent was obtained as part of the online questionnaire in order to collect student responses on their perception of the effectiveness of the SRSs.

The questionnaire included eight questions about student engagement and improved learning outcomes in the engineering module of the course. The first question asked students about their major field of study while questions 2-7 required answers on a 5-point Likert Scale (strongly agree to strongly disagree). Question 8 was an open-ended question which encouraged students to submit their comments through text input.

Intended Benefits

The key benefits of both synchronous and asynchronous quizzes for learning include more detailed and frequent feedback to support student learning. This is possible through in-built analysis of results available during in-class and asynchronous SRSs. Online quizzes will help students study regularly and gain understanding of the course material throughout the semester rather than simply cramming before a comprehensive exam in order to improve their performance. Students are also expected to engage more actively in the class as a result of understanding concepts covered in assigned readings. SRSs are also expected to promote discussion and collaboration among students during class and provide a safe space for shy and unsure students to participate actively. Overall, we expected that students will face fewer difficulties in learning some of the advanced engineering concepts covered in the class as a result of better understanding of fundamentals through additional readings.

The key benefit to teachers include more consistent, efficient, and effective feedback mechanisms to inform course design, identification of learning thresholds, and optimise content delivery. Understanding the strategies and tactics of SRSs and formative assessment will provide insights into learning design with the aim to improving engineering course materials and contingent teaching techniques as previously described by Mathiasen (2015) and van de Pol et al. (2009), respectively. With the implementation of SRSs it is hoped to correctly diagnose students' understanding of in-class as well outside classroom teaching to be able to provide targeted support. For example, teachers can revise learning activities to target specific aspects of learning misconceptions revealed by the SRSs which are particularly useful for students before exams.

The learning success of incorporating effective SRS can be measured via a number of proxies, for example, through:

1. Participation statistics of the SRSs (scores, knowledge misconceptions, number of attempts etc.),
2. Summative evaluation (questionnaire responses),
3. University student evaluation results, and
4. Personal feedback obtained from students, either verbally or through written communication with the teacher.

Results and Discussion

The mean response rate for five in-class quizzes was 76% which correlated well with the average student attendance during the engineering module ranging from 75 to 85 students per lecture. However, the mean response rate for asynchronous quizzes was 90%, indicative of an increased activity outside class time reaching more students which is consistent with findings from the literature (Sappington et al., 2002; Graham, 1999). Students scored on average slightly over 70% for both, in-class and asynchronous SRSs. It showed that students' performance was not affected significantly based on the mode of SRS delivery, whether synchronous during class time or asynchronous.

Forty eight out of 110 students (44%) completed the questionnaire in Qualtrics, based on questions that explored students' perceptions on the effectiveness of SRSs used in the engineering module of the general education course. Figure 1 summarises students' responses to this questionnaire. About three-quarters of the students (73%) strongly agreed and agreed that SRSs were helpful for their learning, increased their engagement with the course and would recommend extending the use of similar SRSs to other course modules, not just the engineering one. Overall, 75% of the respondents also believed that SRS increased their interest in engineering and improved their learning in this subject area of the course.

Based on the responses, it was also evident that the choice of the SRS tool used is important as there was a difference in the preference for tools embedded in Canvas: students tended to prefer quizzes embedded in Canvas (average Likert score was 4.1) compared to quizzes designed in Google Forms (average Likert score was 3.7). One of the possible reasons for explaining this difference could be that students make more use of asynchronous SRS due to the flexibility of time and place (Sappington et al., 2002). Another possible reason could be the familiarity of students with Canvas as it is our university's LMS for all courses.

For the open-ended question requesting comments and suggestions from students, 13 respondents commented. The overall feedback regarding the implementation of SRSs in the engineering module of the course was favourable. Seven of the respondents specifically addressed the SRSs and its positive impact on their learning and particularly for exam preparation which is evidenced in the student comments below:

"…the SRS is useful and easy for me to practice what I have learnt in class by answering those online quizzes."

"Extremely helpful when studying for the exam, provided a rough scope of what to study and let you know what to focus on."

Other students could also see the benefit of extending the use of SRSs to other modules of the course indicating an overall desire to have active learning opportunities across the entire course, not just the engineering module. The following student comment illustrates the benefit of implementing SRSs on learning as perceived by the student:

"I understand that the SRS was only available for the engineering module and this definitely helped my understanding of the content and was useful for the test in revision and practice. For other sections of this course that did not use SRS I definitely did not understand the content as well or do as well in the test as there were no practice quizzes ….whereas I learnt from the answers that were provided at the end of each quiz for the engineering section."

Summative evaluations (SET) that are used university-wide at the end of each course and semester are another source for assessing the effectiveness of teaching methods and the effectiveness of changes to course design. Despite the fact that the end of semester report is typically generated for the entire course, individual teacher evaluations reflect student perceptions on teaching methods implemented in particular modules.

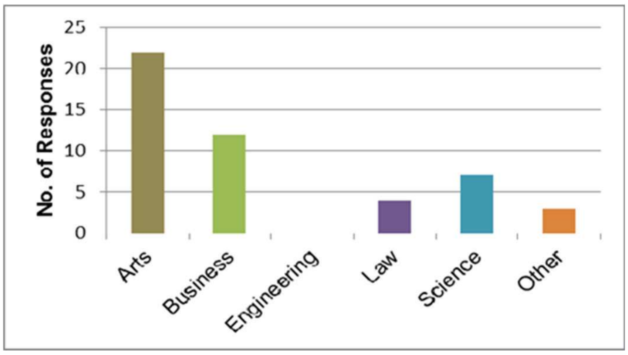
According to the SET report for this course, 78% students were satisfied with the quality of the course, and more importantly, 89% believed that the engineering module was taught effectively (mean score was at 4.3 on a 1 to 5 Likert scale from strongly agree to strongly disagree) due to the implementation of SRSs. Similar to student responses from the questionnaire administered only in the engineering module, comments included in the SET report centred on the effectiveness of practice quizzes and multiple choice questions for optimal learning. For example, one student commented:

"…[the teacher] had variety of content and was engaging in class. I enjoyed how his content asked for perspective, and how the two options were presented, it wasn't so much a case this is right and this wrong. More a case of there are the two options and here are the conditions of both. The revision MCQs were also very helpful."

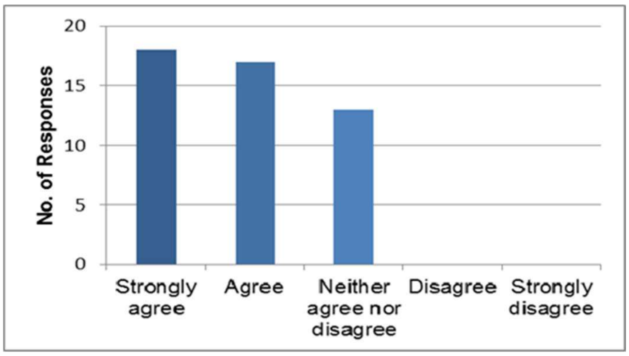
Apart from these documented questionnaires and usage data from the SRSs, verbal and visual feedback is a key element in assessing effectiveness of implemented measures. During the duration of the course, the teacher was approached on several occasions by students, either face-to-face or through email, to express their satisfaction with SRSs, whether used in-class or asynchronous providing practice questions.

In addition to increased attendance, the class interaction level was found to be higher compared to the previous year as students participated actively in discussions on the class topics. Students also appeared better prepared for each lecture and most of them did not struggle with the background material which was fundamental for most of the advanced engineering concepts covered in class. However, further investigations are required to assess students participating in SRSs are more likely to complete the required readings in the context of general engineering education courses where the majority of students will not major in the discipline.

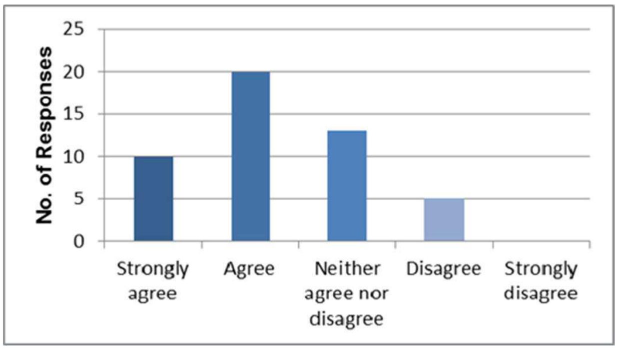
1. **Following is my subject area:**



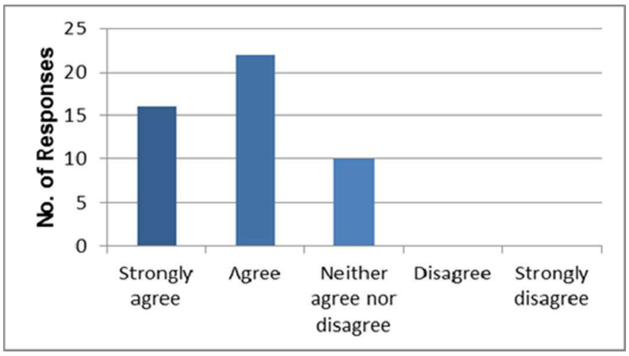
2. **Student Response Systems used in the Classroom were helpful to my learning of the course material.**



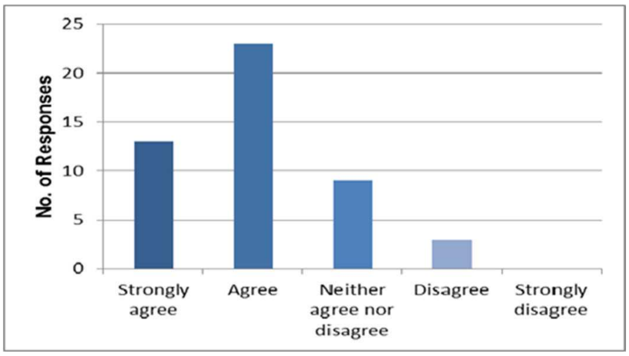
3. **I enjoyed participating in Student Response Systems more through Google Forms (in- class practice quizzes).**



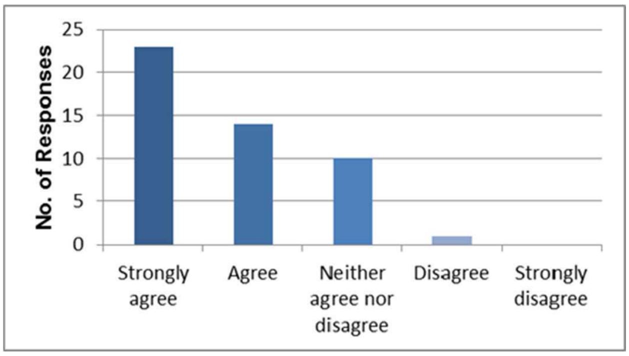
4. **I enjoyed participating in Student Response Systems more through Canvas (practice questions) outside the classroom.**



5. **Student Response Systems increased my engagement in the course.**



6. **I would recommend adding Student Response Systems to other courses as well.**



7. **Overall, Student Response Systems increased my interest in the course and made me better learn the course content.**

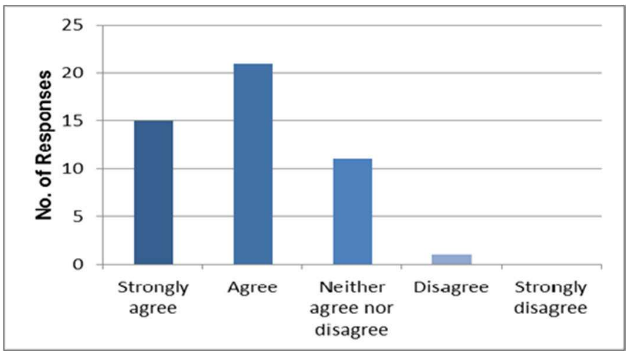


Figure 1: Student responses to questionnaire items for measuring the effectiveness of the SRS

Conclusions

The goal of the study was to include teaching activities in the course design to foster student engagement and provide more scaffolded learning opportunities about engineering concepts targeted at a diverse audience where engineering is not the main area of study. We found that asynchronous quizzes had a greater rate of participation compared to the ones conducted (online) in class. The results demonstrate effectiveness of SRSs in enhancing student learning and engagement in a general education course that teaches engineering concepts to mainly non- engineering students.

Our findings of online administered SRSs as successful tools for enhancing student learning are consistent with similar findings in other fields (Cassady et al, 2001; Dinov et al, 2008; Henly, 2003; O'Dwyer et al, 2007). Therefore, the use of SRSs is highly recommended for any instructor teaching a course that requires students to engage in a significant amount of assigned readings that is beyond students' main area of study and in cohorts with wide-ranging academic interests.

From our experience, it is advisable to provide both synchronous and asynchronous learning opportunities to maximise student engagement. Moreover, it would be interesting to investigate the effects of 'written quizzes' versus 'online quizzes' on student engagement and learning outcomes. However, reduced costs, increased efficiency of analysis, and ease of setting up SRS make online administration much more appealing compared to the collection of responses on paper, particularly in large class settings. In addition, the truly formative nature of SRSs by providing students with the opportunity of multiple attempts at solving a problem and immediate feedback not just for students but also teachers can only be attained in the online format. It should be noted that online quizzes are just one of the many tools available for SRSs but are one of the most effective due to some of the advantages mentioned above.

In summary, students' responses to the question 'Overall, Student Response Systems increased my interest in the course and made me better learn the course content' support the observation that SRSs effectively implemented using online tools can enhance student learning and engagement in the classroom. While this exact question has not apparently been posed in the literature, variants on the same theme have been and the results from this study are found to be in agreement with this notion (Kibble, 2007; Angus and Watson, 2009).

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First year engineering students' problem solving in different scenarios

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SESSION S2: Educating the Edisons of the 21st Century

CONTEXT Engineers solve problems as an integral part of their work environment. Solving problems (e.g. defining problems, analysing problems, interpreting information, transferring concepts), has been determined as a significant generic engineering competencies that engineers graduating in Australia require. To do so successfully, they must consider a range of choices taking into account all appropriate factors before reaching a final decision. First year engineering students bring with them a dearth of engineering experience to their studies and make decisions based on limited knowledge and approaches to problem solution. This paper investigates the experience of utilising alternative scenarios using 'new' thinking approaches on the development of different methods to solving a materials selection problem of engineering components. Student thinking is often limited in scale to one "size" and when exposed to "unlimited" inputs, outcomes may be significantly different.

PURPOSE This research aims to answer the question "how does a change in approaches to thinking in solving engineering problems influence a first year student's decision making process." We are trying to understand how students think when exposed to situations which they would not normally consider (or unusual or out of the ordinary).

APPROACH At the end of their first year studies in materials engineering, students were presented with a problem of selecting a material and manufacturing process for an engineering component. They were given a minimalist brief and had to rely on their previous knowledge. Once they arrived at their solution (often a closed format) they were then asked to consider alternative scenarios where the selection process allowed them unlimited resources and time, or extremely limited resources and time. An online survey requiring verbal answers was established to determine students' approach to their decision making based on their thinking process. The results were analysed according to aggregation of similar verbal responses, to determine changes in thinking as a result of open ended scenarios

RESULTS Analysis of results has indicated that first year students' answers to the open ended questions resulted in vastly different approaches to problem solution. Where resources were unlimited, seemingly "unrealistic" solutions were proposed in terms of time, finances and engineering capabilities; and where very limited resources were proposed, very simple or less complex engineering solutions were proposed.

CONCLUSIONS When students are presented with an engineering problem at first they proposed a closed form (standard) solution. However, when allowed to expand their approach, where their resources are either unlimited or extremely limited, either "unusual" or simple proposals are developed. By extending the student thinking to the extremes, they are challenged in their thinking and decision making processes. These results may indicate how students can approach decision making processes later in their engineering career.

KEYWORDS Thinking, problems, competencies.

Introduction

Engineers solve all sorts of problems, often needing to create elegant solutions while working within various limitations. Every potential answer an engineer devises for a problem must be weighed against the realities of the physical world, available materials, and a finite budget (Lawlor, 2014; National Academy of Engineering, 2004). It takes creativity to move successfully from problem to solution, all while navigating a mesh of limitations (Cropley, 2016; Felder, 1987). Engineers Australia, as well as international engineering bodies, has developed a set of competencies (i.e. defining problems, analysing problems, interpreting information and transferring concepts), which every engineering graduate must attain as a problem solver (King, 2008; Male, Bush, & Chapman, 2009; National Academy of Engineering, 2004). First year engineering students bring with them a dearth of engineering experience to their studies and make decisions based on limited knowledge and approaches to problem solving. Creative problem solving may be difficult for these students' entering their first year of engineering studies, where their high school studies have been rigidly structured and problem-solving is well defined according to specific criteria. Students often see engineering problem solving as a systematic and dispassionate process of applying impartial scientific principles or truths, overlooking the human dimension in engineering problem solving and for which not all the information is available.

Learning how to approach and solve problems, which relate to real world situations, is an integral part of an engineering students' education. Systematic engineering problem solving has been the subject of a number of textbooks, e.g. (Carmichael, 2013; Cropley, 2016) and introduced as formal courses in for example, a number of Australian engineering institutions (UNSW, 2017; USQ, 2016; Victoria University, 2016). Structured engineering problem-solving teaching seem to follow a well-defined formulaic approach, but not always allowing any room for creativity, originality, or inventiveness. Jonassen *et al* (2006) highlighted the problems in the workplace as being significantly different from that found in the classroom and often requires different thinking. Similarly, a structured education approach (e.g. the teaching of solution strategies "problem" subjects) often results in problems with well-defined solutions, involving a number of well-defined steps as summarized by Carmichael (2013) and Cropley (2016); identification of a need; problem definition; search; constraints; criteria; alternative solutions; analysis; decision; specification; and communication often resulting in one solution, constrained within well-defined boundaries.

Student thinking is often limited in scale to one "size" and when exposed to "unlimited" inputs, outcomes may be significantly different (McNeill 2016). Hence, the work outlined in this paper investigates the influence of students' experience of alternative solutions to problem-solving using "new" thinking approaches employing the principle of TRIZ (Altshuller, 1984). The process of problem-solving for our students is implemented according to systematic and organized steps, allowing the students to be guided to a solution. During this process, students learn to analyse, evaluate, and make conclusions, while at the same time, they apply their critical thinking skills, which may include the human aspect.

Problem-solving for engineering students

The introduction of TRIZ (Altshuller, 1984), especially in the engineering curriculum has enhanced the thinking skills of engineering students in their approach to problem-solving (Moehrle & Paetz, 2014). In their analysis of data from the introduction of TRIZ into the engineering curriculum, their results indicated that teaching students "open-ended" problem-solving skills provided them with confidence in approaching difficult or unknown problems (Moehrle & Paetz, 2014; Orloff, 2016). The students involved in these studies were all exposed to techniques of using TRIZ in different problematic scenarios by considering various scenarios, e.g. MATCEMIB (Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular & Biological) as hints to problem solution (Valentine 2017).

A significant technique employed within the TRIZ approach is known as the DTC (Dimension-Time-Cost) or STC (Size-Time-Cost) method (Belski & Skiadopolous, 2017; Frenklach, 1998). In this method, the DTC/STC operator is aimed at improvements by changing: the dimensions of the system from maximum to zero; the time from infinite to zero; and the cost of the system from maximum to zero. The DTC is now commonly referred to as the STC (size, time, and cost) operator and is a simple heuristic from the TRIZ family, which is used to frame and reframe problems and to generate solution ideas. Once the students have generated a solution, they are asked to consider solutions, which involve minimizing and maximizing their proposal. The so-called STC operators under six constraints: Size = 0 & ∞; Time = 0 & ∞; Cost = 0 & ∞; and involve five steps, which are given in Table 1.

Table 1. Size-Time-Cost (STC) Operator: five Steps under six constraints (Size = 0 & ∞; Time = 0 & ∞; Cost = 0 & ∞)

Establish the Object and the means to achieve Improvement
Consider the Object under six constraints (Size = 0 & ∞; Time = 0 & ∞; Cost = 0 & ∞)
Reflect onto the task under these six conditions and propose solution ideas
Consider the means to achieve these solutions under six constraints
Reflect onto the task under these six conditions and propose solution ideas

Research Question

The research question our work aims to answer is: "how does a change in approaches to thinking in solving engineering problems influence a first year student's decision-making process”. We are trying to understand how students think when exposed to situations, which they would not normally consider (thinking unconventionally, or from a new perspective).

Participants

Participants were recruited from the full cohort of freshmen (first year engineering students) studying the core subject of Engineering Materials during semester 1, 2017 at a university in the south east of Australia. An introductory course was chosen because it was assumed that students had a basic understanding of physics, chemistry, and mathematics. 110 undergraduate engineering students participated in this study (with 93 responding to the survey). The majority of participants had completed either physics (47%) or physics and chemistry (39%) in their last year of high school, as well as mathematical methods (58%) and a combination of mathematical methods and specialist mathematics (35%). A minority of students had not completed any physics (13%) or mathematics containing calculus (8%). Participants were predominantly majoring in civil engineering (41%), followed by robotics and mechatronics (24%), mechanical (18%) and telecommunications and electrical (17%). Participants primarily described themselves as first year undergraduates in their first year of studies in an engineering course (91%).

Method

Towards the end of their first year subject of materials engineering, students were presented with an open-ended problem in blended mode; i.e. although there were no face-to-face tutorial or laboratory activities associated with the activity information, students had access to online information and face-to-face consultations from their tutors. The student cohort comprised into six laboratory groups, each consisting of approximately 20 students. Students completed their laboratory activities in groups of two. The materials selection activity commenced during week 8 of the 12-week semester and was to be completed by week 11 (i.e. students had three weeks to complete the activity). It was an open-ended material selection exercise where the various student groups were provided with an engineering component and were required to determine appropriate selection of materials and manufacturing processes. The materials selection activity comprised an exercise "to select materials based on properties, manufacturing, sustainability, available time, cost, and performance.” The engineering components available for selection were allied to major engineering disciplines and were both familiar and alien to the students, viz. bridge building materials; hand tools; and home construction items.

For the first task of the activity (which was assessed), students were presented with the instructions and the grading rubric, and were then asked to begin their activity, which was required to be completed within seven days. Students submitted their work, which was saved in the Learning Management System (LMS). The students submitted a one page “memo” report and gave a three to five minute oral presentation substantiating their response to the selection process, similar in procedure to business presentation for an industrial company. Students submitted the memo report and oral presentation. They were then thanked for their involvement, and asked to undertake a second and related activity. At no stage were the students given any training or information in the requirements of the selection procedure.

For the second task of the activity (which was not assessed), the students were invited to voluntarily complete a survey concerned with their “thinking” approach and an examination of alternative strategies to the materials selection process, based on the STC approach (TRIZ, 2017). During this phase of the activity, each student was required to provide ‘open-ended’ solutions (where restrictions on size, time, and cost were removed) to the original problems in a reflective environment. Not all the students responded to the optional second task of the activity, and they were not penalised in their overall assessment.

For open-ended problem, students were briefly guided in a lecture environment on how to interact and extract information using a learning management system (Blackboard©) and the website which contained a repository of related information (TRIZ, 2017). The repository explained the STC operator procedure and approaches to obtaining a set of solutions. The students were not given any training in thinking processes, or materials selection methodology. They were required to rely on their previous knowledge obtained from the early content of the subject, their previous experiences, and their interaction with the outside world of engineering, both through the WWW and physical contact, as well as incorporating many of the competencies. Professional and personal attributes) are those required by Engineers Australia (Engineers Australia, 2017).

Survey details

The students were required to “reflect on the problem under specific conditions and propose solution ideas,” following their initial submission of the engineering problem-solving task.

Table 2. Grouped Survey Questions (based on the STC approach).

Engineering material based	
Q1.1 What material would I use to construct the object if the Size of the object was infinitely small?	Q1.2 What material would I use to construct the object if the size of the object was infinitely big?
Q2.1 What material would I use to construct the object in a very short period of time?	Q2.2 What material would I use to construct the object if I had infinite time?
Q3.1 What material would I use to construct the object if I had zero budget?	Q3.2 What material would I use to construct the object if I had an infinite budget?

The survey consisted of six open-ended questions each with two parts, and was based on the students’’ response to the STC questions (as given in Table 2). It is important to acknowledge that open-ended questions have a great diversity of responses (Geer, 1988).

The instructions were: “we wish to identify your thinking processes and approach to solving the materials selection assignment. The whole process will take about 10-12 minutes.”

Data Analysis

Firstly, similar statements, phrases, or keywords related to the research question. During this phase were *identified*; our concerns were not with duplicate but similar terminology. The second stage focused *grouping* together similar statements, phrases or keywords related to the research question, whereas the third phase involved looking back into the data for connections amongst the groupings. The authors themselves reviewed the data in accordance with guidelines developed in agreement with the recommendations of Miles, Huberman, and Saldana (2013) and had a Cohen kappa inter-coder reliability of 90% (Cohen, 1960). The survey results were analysed according to aggregation of similar written responses, to determine changes in thinking as a result of open ended scenarios utilizing thematic text analysis where there is an occurrence or co-occurrence of words or themes (Popping, 2015). The text analysis was analysed according to the scheme developed by Montgomery and Crittenden (1977) so coding involved “locating relevant information within a larger context as well as evaluating the relative importance of two or more possible responses to arrive at a single code,” based on human judgments. Linguistically similar features of responses were grouped in sections for the engineering components in order to arrive at comparable groupings.

Findings and Discussion

When students responded to the first engineering activity for realistic solutions to the materials selection problems, they all selected either one of two classes of materials for the engineering components, i.e. metals (e.g. varieties of steel, aluminium, or composites). Because of the range in qualitative responses received, similar answers, were grouped and collated.

When students were asked to reflect on their responses using the TRIZ (STC) approach (according to Table 3, Q1.1-Q2.1; Q2.1-Q2.2 and Q3.1-Q3.2 a variety of traditional (steel, aluminium and wood) and non-traditional materials (titanium, carbon nanotubes, graphene, diamond, ceramics, and gold) were selected for the various constraints. A summary of the materials chosen for bridge building, hand tools, and home construction are given in Figures 1, 2, and 3 respectively. Responses shown in Figure 1 indicate that there was not a trend for any of the STC operators whether small or infinite. For example for infinitely small, carbon nanotube/graphene was chosen, whereas for short time either wood or steel was chosen, and for zero budget, wood was chosen.

Considering the opposite end of the spectrum, when infinitely big, students chose metals (high strength), for infinite time they chose again high strength metals and for infinite budget the students selected almost equally high strength metals and carbon nanotube/graphene. It was only for infinitely small size or infinitely large budget that the section was non-standard i.e. not a steel but carbon nanotube/graphene. In the area of home building materials, responses are shown in Figure 2, which indicate that when materials selection is governed by time there was not a trend for any of the STC operators; whether small or infinite. For infinitely small size artefacts, polymers, followed closely by ceramics/glass/diamond were chosen, and for short time periods, wood, followed by ceramics/glass were chosen, whilst for zero budget, wood was clearly chosen.

Considering the opposite end of the spectrum, when infinitely big, students chose metals, when they had infinite time; they chose almost equally ceramics/glass/diamond and metals, and for infinite budget the students selected ceramics/glass/diamond followed by metals. For all STC “large” cases, it interesting to note that metals were either the highest or next to highest on the selection list. Drilling down further into this data showed that it was non-traditional metals such as titanium, which comprised most of the metals list.

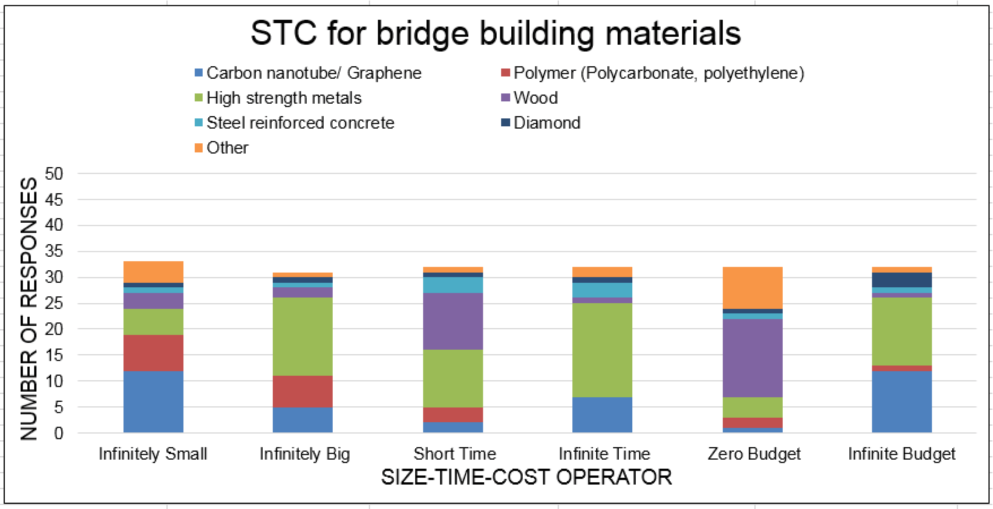

Figure 1. Materials for bridge building materials selection according to the STC approach.

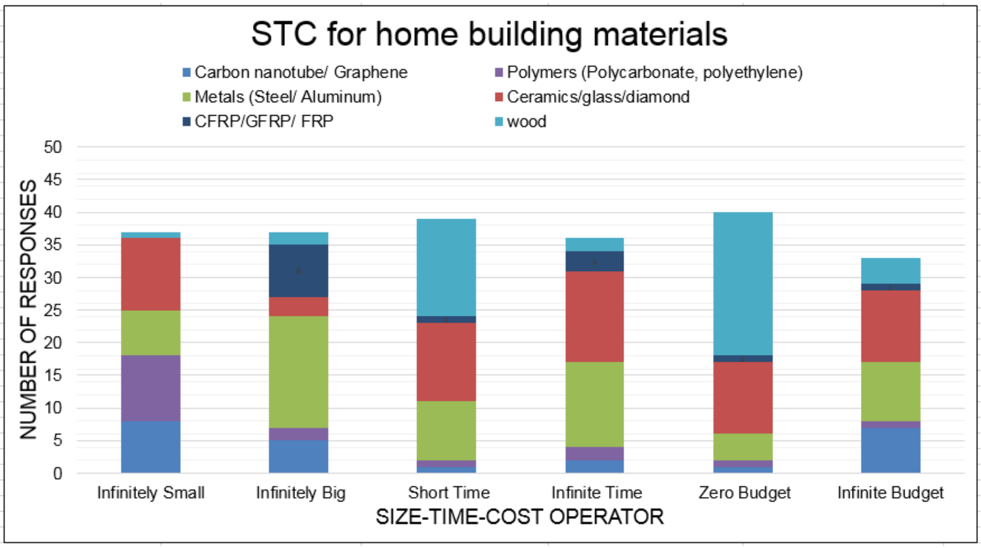

Figure 2. Materials for home building materials selection according to the STC approach.

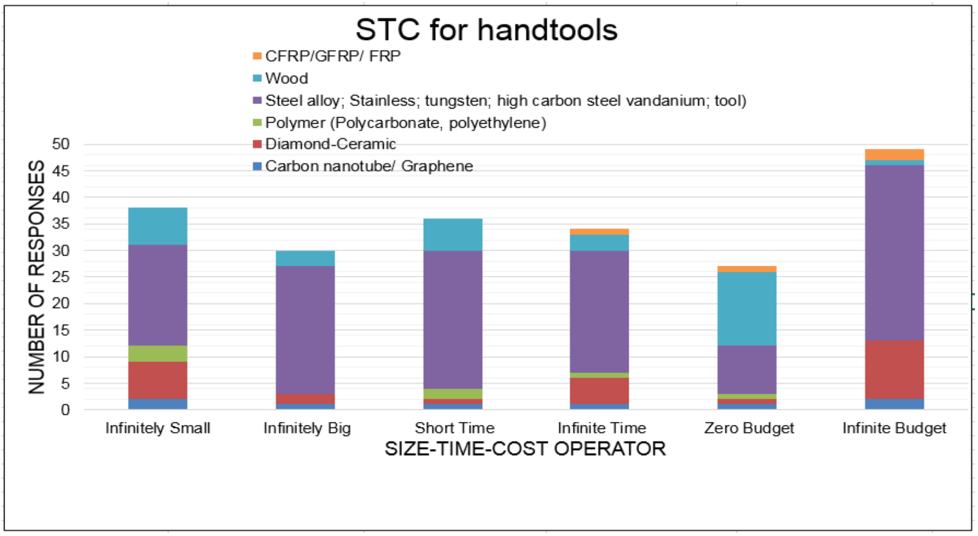

Figure 3. Materials for hand tools materials selection according to the STC approach.

Moreover, in the third area, of hand tools detailed responses are given in Figure 3. Analysis of responses for selection of materials for hand-tools also dictated by time, also show that there was a definite trend for all of the STC operators whether small or infinite. In all cases, the predominant material for selection was a metal. Again, drilling into individual data components for metals, showed that the selection was not confined to steel or aluminium, but now also included tungsten, titanium, tungsten and vanadium, exotic metals.

The results from this study are similar to those found by Wertz, Purzer, Fosmire, and Cardella (2013) for students' ability in retrieving information from the web, and importantly, similar to findings from Ashby (2015) where students were required to undertake a case study for selecting wind farm components and reflect upon their decision. The results of this work were in agreement to that of a number of authors (Belski &Skiadopolous 2017, Moehrle & Paetz,2014, and Frenklach,1998), in that allowing students to be free from traditional thinking approaches results in a significant number of unconventional/familiar solutions which may subsequently be the precursors to actual solutions. It is interesting to note that the students selection of components of the STC operator was in no way influenced by the lecturer, but was solely developed using blended/online delivery of information and relying on the students' own acknowledge and skills.

This qualitative survey does have limitations. The control experiment was that of the same cohort of students who were first asked to submit a traditional engineering solution (using a variety of information resources, web, journals, books), and after completion, reflect upon a constraint-free approach. This change in their approach to materials selection was developed (learned) by the students based on the information they received using the LMS and Edison21 (TRIZ, 2017). The students were guided to learn independently, and use the STC tool themselves when faced with a problem to solve in the future: a new achievement.

Closing remarks

Students can be exposed to a variety of problem-solving strategies based upon traditional engineering solving techniques. These techniques are all constrained by specific engineering requirements, leading to traditional solutions. However, when constraints to size, time, and cost (STC) are removed, inspired, but not always practical solutions may be developed. From these solutions, further refinement may arrive at solutions, which provide optimization of any of cost, time or size restraint. The conclusions of this activity are that giving students constraint-free activities often resulted in uncommon solutions to engineering materials selection problems, whilst keeping in mind that standard solutions were also applicable.

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Assessing the efficacy of embedding online laboratories in e-learning tutorials to enhance student engagement and satisfaction

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SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

The ever-changing landscape of online learning presents inherent technical and pedagogical challenges regarding student engagement, satisfaction and the application of knowledge, skills and abilities. The lack of face-to-face delivery defines the need for e-learning strategies to foster student engagement and supply industrial credibility. This e-presence is conventionally achieved via the use of synchronous online tutorial sessions (using web and video conferencing) or online laboratories.

PURPOSE

The purpose of this work is to examine an identifiable gap in the current research; the efficacy of embedding these remote and virtual laboratories into contextualised online synchronous tutorial sessions.

APPROACH

The impact of this strategy is evaluated by studying educators and students undertaking online engineering programs at The Engineering Institute of Technology (EIT). The study uses three different research methodologies to determine the student and educator reaction, the effect on learning and the technical challenges in implementation.

RESULTS

The key results indicate a strong preference (greater than 73% of students surveyed) in favour of embedding labs in tutorials as opposed to having tutorials without embedded laboratories. In addition there is a basis indicating an overall improvement in performance of students who received tutorials with embedded laboratories as opposed to those that did not.

CONCLUSIONS

This paper concludes that the use of remote and virtual laboratories during live online tutorial presentations improves the reaction of students and measurable learning outcomes. The majority of students found significant educational benefits in attending these sessions as compared to tutorial sessions without embedded remote laboratories; verified by subsequent grade improvements. This was expected; relational learning and student engagement increased and was accompanied by a reduction in the uncertainty and unfamiliarity with remote and virtual laboratories.

KEYWORDS

E-learning; online learning; remote laboratories; virtual laboratories; interactive tutorials.

Introduction

Over the past decade, there has been a proliferation of remote or distance learning using the internet (often referred to as e-learning or online education) in the engineering education areas (E. Allen & Seaman, 2006; Bersin, 2004; Bonk & Graham, 2006; Ma & Nickerson, 2006; Rossett, 2001). Typical approaches for e-learning are web-based (asynchronous) and streaming of video (synchronous) over the internet (Rossett, 2001). The two forms of learning are illustrated in figure 1.

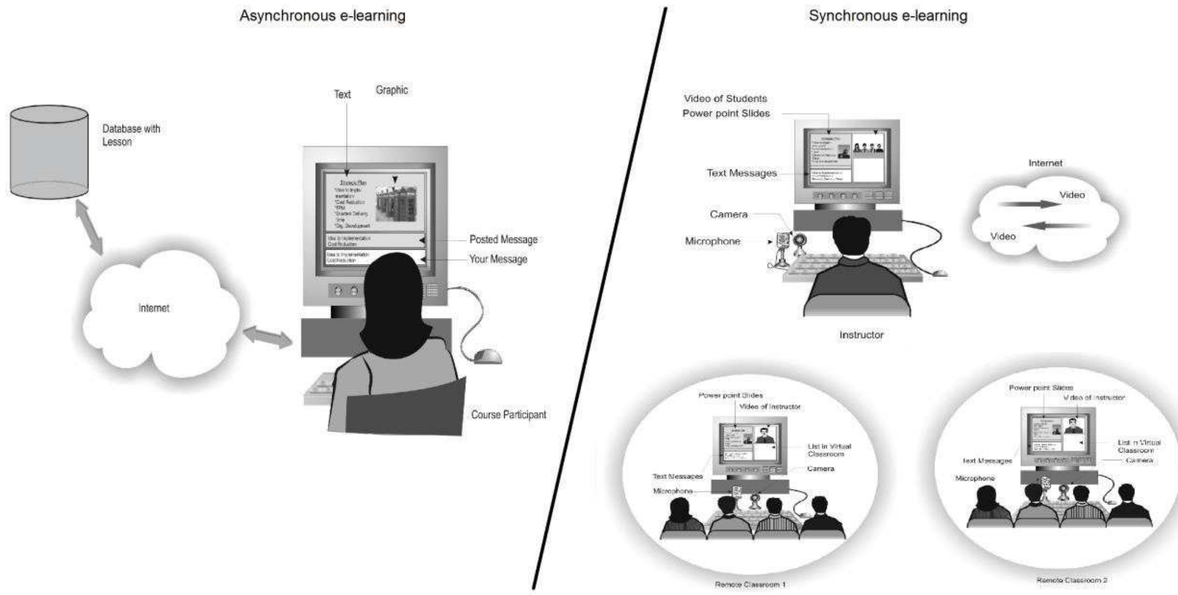

Figure 1: Asynchronous vs Synchronous e-learning

Almgren and Cahow (2005) believed that the factors responsible for improving computer-based engineering education were a desire to increase active and discovery learning, a desire to make lab facilities available to the wider community and to provide students with more meaningful practical experiences. They believed that the appeal for remote (or online, as they termed it) labs is due "to the increasing demand for active learning and flexible education, and for the appeal of implementing techniques of learning via discovery" (Almgren & Cahow, 2005, p. 3). These comments are supported by the research conducted by M. Phillips (2006), where respondents noted the need for more "hands-on" training and concerns that e-learning may not provide it.

Kanyongo (2005) referred to L.J. Smith (2001) who listed the benefits of e-learning as being "accessibility, flexibility, participation, absence of labelling, written communication experience and experience with technology" (p. 1). On the other hand, L.J. Smith (2001) listed the problems for e-learning being that of "team building, security of online examinations, absence of oral presentation opportunities and technical problems" (p. 1). Brown and Lahoud (2005) noted the remarks of Moore and Kearsley (1996) that courses delivered at a distance can be as good as that of traditional classroom instruction. The synchronous form of e-learning – being live and thus perhaps more interactive will be the focus of this research.

One of the areas of increasing interest in e-learning is the use of remote laboratories or simulation software; an interactive hands-on approach to improve the learning experience. There are generally two challenges with e-learning, the lack of interaction with the instructor and the difficulty of providing real tools for practical exercises and to facilitate applied learning (Cooper, 2000; Cooper et al., 2003). These two issues are addressed in this research.

Schank (2002) pointed out that many users commented on the poor quality of e-learning. Although Shank (2002) was thinking along more general lines, he stated that learning by doing was an essential part of the learning experience to enhance the absorption of material.

Learning by doing works because it strikes at the heart of the basic memory processes that humans rely upon. We learn how to do things by assessing the efficacy of our efforts. We learn when the rules apply and when they must be modified. We learn when our rules can be generalised and when exceptional cases must be noted. We learn when our rules are domain bound or when they can be used independently. We learn all this by doing, by integrating these experiences into existing memory structures (Schank, 2002, p. 5).

Huntley, Mathieu, and Schell (2004) defined a laboratory (or lab, as it will be henceforth referred to, for brevity) “as a room or building containing specialised equipment” (p. 398). Lindsay (2005) noted that a typical lab class “comprised a small group of students, and a demonstrator (often a postgraduate student), grouped around a piece of hardware located in a lab. Students typically conduct a series of experimental procedures as outlined in the lab handout, they record the data from the hardware, and they write up a report based on this data and the underlying theory in the week or two subsequent to the session” (p. 44).

Gandole (2005) added to this by remarking that a lab “should aim to encourage students to gain: manipulative skills, observational skills, an ability to interpret experimental data, an ability to plan experiments, interest in the subject, enjoyment of the subject, and a feeling of reality for the phenomena talked about in theory” (p. 49).

Colwell et al. (2002) noted that practical work and executing experiments help those students studying science and engineering subjects. They quoted from Hewson and Hewson (1983) who stated that these students need to engage in knowledge construction; a difficult undertaking as they “need to develop both conceptual and procedural understanding by appropriate actions” (Colwell et al., 2002). Jochheim and Roehrig (1999) noted that experiments with live processes and real equipment provide engineering students with the expertise needed to tackle engineering problems and improves their motivation. He added that many physical phenomena are difficult to understand if written or explained in words; they must be witnessed in action.

Lahoud and Tang (2006) pointed out that many distance learning students found that traditional lab experiments were not an option due to geographical separation. They suggested offering some form of virtual or remote lab environment for distance learning students. They described the two possible solutions:

- Virtual labs comprising simulation software running on a host machine. (They point out two issues: students may struggle to achieve the required skills and practice and servers which are powerful and expensive are often required to make the simulations as realistic as possible).
- Remote labs are equivalent to the traditional lab environment as they involve real equipment, (An issue was noted; the labs are situated at a significant distance from the learner).

Ma and Nickerson (2006) referred to the impact of information technology with the creation of simulated labs and remote labs as useful alternatives to the traditional conventional labs. They pointed out that the effectiveness of these two new lab approaches, as compared with the traditional hands-on labs, was not examined in much detail in the research literature. They felt, however, that the remote and simulated labs were an excellent way to share specialized skills and resources over a wide geographical area by reducing overall costs and improving the educational experience. Azimopoulos, Nathanail and Mpatzakis (2007) concurred with this and emphasised the need for practical work as an important adjunct to the theoretical study.

Esche (2005) listed the benefits of the remote labs for students, suggesting that they: offer a more comprehensive experimental experience, offer a more accurate representation of a hands-on experience, optimise the students' imagination and enthusiasm, allow for more flexibility; instructors and students are not required at the same time, promote self-learning, and allow for a more integrated self-assessment approach. Insofar as the instructors (and their institutions) are concerned, the benefits include: easily adding lab demonstrations into their instruction, monitoring the lab performance of students more rigorously, fewer scheduling problems with large student numbers and fewer lab personnel required, more flexible financial planning for expensive equipment, and greater levels of safety.

A slightly more negative perspective was provided by Albu, Holbert, Heydt, Grigorescu and Trusca (2004). They suggested that remote labs were not as effective for training engineering students for the following reasons: the handling of real equipment is limited; there are fewer real world problems such as loose wiring and electrical contacts and students are shielded from connecting equipment incorrectly. They suggested using remote labs as a prelude to real laboratories.

This research investigates the impact on learning when synchronous e-learning is used and is combined with remote and virtual laboratories.

Purpose

The purpose of this work is to examine and address the following research questions regarding the student experience of live web and video conferencing supplemented by remote and virtual lab exposure:

- What are the reactions of student and educator when this approach is used?
- What is the effect of the strategy on student learning?
- What are the technical challenges when implementing this strategy and can they be remedied?

Approach

Various research approaches and methodologies, such as paired T test and analysis of variance were considered. For Method 1, similar to Tuysuz (2010), a two-tailed paired samples T-test was used to analyse student grades between control and experimental groups, to determine any significant difference to a 95% confidence interval. The Tuysuz (2010) study also focused on both knowledge and attitude metrics (measured here in Method 3), regarding virtual laboratories. Other papers, such as Alghazo (2010), have similarly used final grades as a metric for determining significant differences in teaching styles, in the case of Alghazo, determining "no significant differences in the effectiveness of distance education and traditional classroom education".

In Method 2, due to the small sample size and number of questions, the confidence interval method was not used and instead, the performance of each group was divided into sets using question 1 and question 2 and the mean results compared.

For Method 3, in a similar approach to Tisdell (2016), the confidence interval was applied to the Likert scale test in evaluating perceived student engagement.

Method 1

The first method is to determine if the use of live lab demonstrations impacts on student grades. This method aims to compare student grades, for one unit in particular, by looking at individual assessments and total unit grade averages over two cohort intakes. The same unit is compared over two different cohorts of known delivery methodology. The content is kept the same in both cohorts to ensure consistency of content being delivered. The difference: one delivery cycle did not have embedded online lab demonstrations in tutorial sessions, while the other more recent delivery cycle included live embedded online lab demonstrations.

The unit used for this comparison is titled - “Industrial Process Control Systems” and is at the Coursework Master Degree level.

The first delivery cycle, without embedded online labs, was delivered in 2015, 2nd semester. The tutorials mainly consisted of theoretical and image based explanation of the various control concepts EIT, 2015). Tutorials were one hour in length and delivered once per week over 12 consecutive weeks.

The second delivery cycle, with embedded online labs, was delivered in 2016, 2nd semester. In this unit, the tutorials consisted of embedded lab demonstrations. These lab demonstrations were delivered in tutorial sessions by means of in session screen- or lab-share, with the lecturer detailing and demonstrating various real-time aspects of advanced control theory. At least half of the tutorial lectures included embedded online labs and these were included early on in the unit delivery (EIT, 2016). Tutorials were one hour in length and delivered once per week over 12 consecutive weeks.

At the end of both units, students were required to complete two major assessments. These assessments were report-based, but they also required students to use lab software. This lab was merely explained in the first delivery cycle, but embedded in the second delivery cycle. The resulting grades for each of these cohorts was then derived and compared in order to ascertain whether the changes to the tutorial delivery had any impact.

A second unit was selected as a control variable; to calibrate the study unit results and account for the differences in student ability. This unit was delivered in parallel with the study unit “Industrial Process Control Systems” in each of 2015 and 2016 respectively. The control unit was delivered to each cohort identically and did not include embedded online lab demonstrations in its tutorial sessions. The grades for the same students in each respective cohort were then compared and used to determine whether there was any significant difference in average student ability between the cohorts which would impact the study unit results.

Method 2

The second method assessed students and educators across a range of cohorts and engineering disciplines based on the content of a custom 30 minute live tutorial on the subject of robotics and autonomous vehicles. The attendees were split into two groups.

Group A received a live tutorial without any remote or virtual lab demonstrations that covered topics ranging from the basics of robots and control theory to simultaneous localization and mapping (SLAM) and the D star search algorithm.

Group B would receive a live tutorial covering the same content with the same basic slides; however the second-half of the webinar was abridged and the additional free time was dedicated to illustrating the concepts through the use of remote and virtual lab demonstrations which included a Lidar/SLAM robot navigating around obstacles and a graphical representation of the D star search algorithm using a C# program.

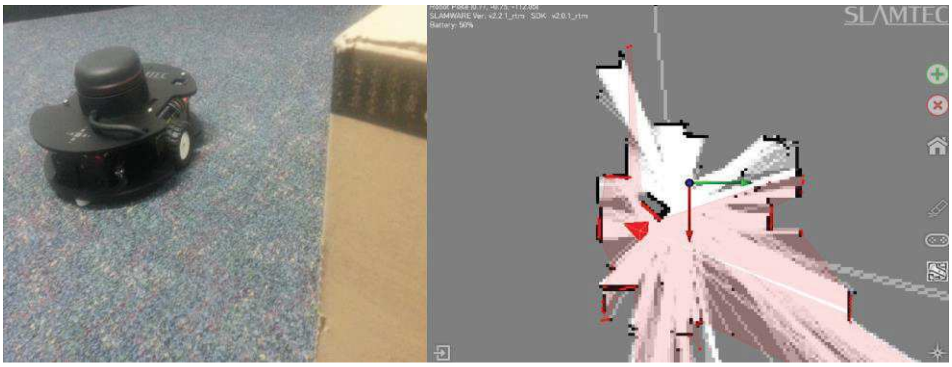

Figure 2: Lidar/SLAM robot lab demonstration

Following each live tutorial, each individual was assessed on what they had learned using an identical multiple-choice quiz with two questions (each with four options). The quiz for both Group A and Group B was structured as follows:

- Question 1: A question to select the correct statement, for which the options are based on the content delivered in the identical first half of each group's tutorial. This was used as the control variable for the experiment as students from each group had received the exact same material needed to answer this.
- Question 2: A question to select the correctly depicted scenario given the following: "A robot toy car (shown in red) can move horizontally or vertically to crosses on the grid. The robot has assigned costs to each of these crosses (nodes) on the map including the brown walls but it is not aware of the grey wall, which has just been introduced. Its goal is to move to the blue circle following a path shown in green. Using the D* (D star) algorithm, which of the below shows its most likely initial guess at a path?" Four different illustrations were given, each showing a different path that the robot could take. This was based on the second half of each tutorial where, although both Group A and Group B had been taught how the D star search algorithm works using examples, Group A was limited to explanations and slide illustrations whereas Group B had online lab demonstrations in addition to the abridged explanations and slide depictions delivered to Group A.

The tutorial attendance was captured and used to verify the quiz submissions, administered and collected using SurveyMonkey. The quiz results were then compared between the two groups (EIT, 2017).

Method 3

The third method comprised of a four question survey in which students were asked to indicate how strongly they agree or disagree with the following statements (as questions) on a 5-point Likert scale rating by selecting one of; Strongly Disagree; Disagree; Neutral; Agree; Strongly Agree:

- Question 1: Online laboratories (software simulations or hardware with webcams) are effective in helping me to understand engineering topics.
- Question 2: Online tutorials that include online laboratory demonstrations are more effective than online tutorials that do not include online laboratory demonstrations.
- Question 3: I would like to see more online laboratory demonstrations in my engineering course.
- Question 4: I feel better equipped to complete my practical assignments when online laboratory demonstrations are included in my course's online tutorial sessions.

The survey was sent to 496 students who have been studying for a period of at least 6 months with EIT and thus have encountered online laboratories. The responses were then collected and tabulated (EIT, 2017).

Results

The results of each method are as follows:

Method 1

For the determination of embedded lab impact on student grades in historic delivery cycles, the results are as follows: The first delivery cycle in 2015 had 32 students in the cohort and the second delivery cycle in 2016 had 9 students in the cohort. The grades of the two major assessments and their unit average are detailed in Table 1 below, where a 95% confidence interval is used to determine whether p<0.05, $\bar{x}$ is the mean (%), and σ is the standard deviation:

Table 1: Average grade performance (%) for compared delivery cycles

Experimental Unit	2015 Delivery cycle 1			2016 Delivery cycle 2			t	p
	n	$\bar{x}$	σ	n	$\bar{x}$	σ		
Assessment 1:	32	74.19±5.17	14.93	9	81.22±6.63	10.14	1.08	0.31
Assessment 2:		77.38±2.52	7.27		79.78±9.86	15.09		
Unit Average:		83.38±2.02	2.02		86.56±5.7	8.73		

Table 2: Control unit average grade performance (%) for compared delivery cycles

Control Unit	2015 Delivery cycle 1			2016 Delivery cycle 2			t	p
	n	$\bar{x}$	σ	n	$\bar{x}$	σ		
Unit Average:	32	82.25±5.65	16.32	9	82.63±10.2	17.26	0.06	0.95

Method 2

The results of the post-tutorial quiz are provided in the table below. 14 students/educators attended the Group A session, whereas 22 students/educators attended the Group B session.

Table 3: Post-tutorial quiz results for compared groups

Student Results	Group A	Group B
Q1 correct	11/14 = 78.57%	15/22 = 68.18%
Q2 correct	7/14 = 50%	12/22 = 54.54%
Q1 correct & Q2 correct	5/14 = 35.71%	11/22 = 50%
Q1 correct & Q2 incorrect	6/14 = 42.86%	4/22 = 18.18%
Q1 incorrect & Q2 correct	2/14 = 14.29%	1/22 = 4.54%
Q1 incorrect & Q2 incorrect	1/14 = 7.14%	6/22 = 27.27%

Method 3

Out of 496 students surveyed, 69 responded (13.9%), whose preferences are illustrated below:

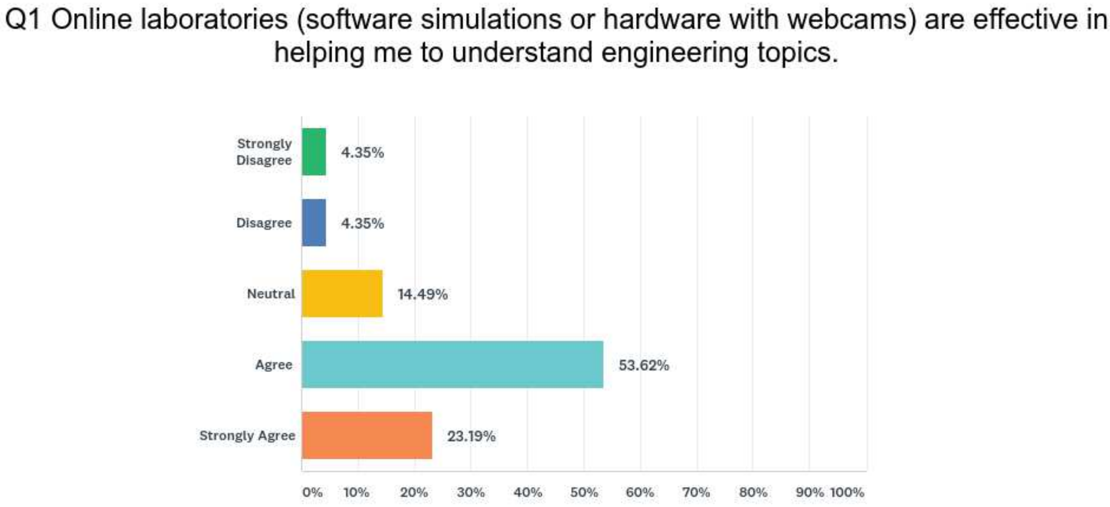

Figure 3a: Q1 Results of the survey for tutorial quality improvement.

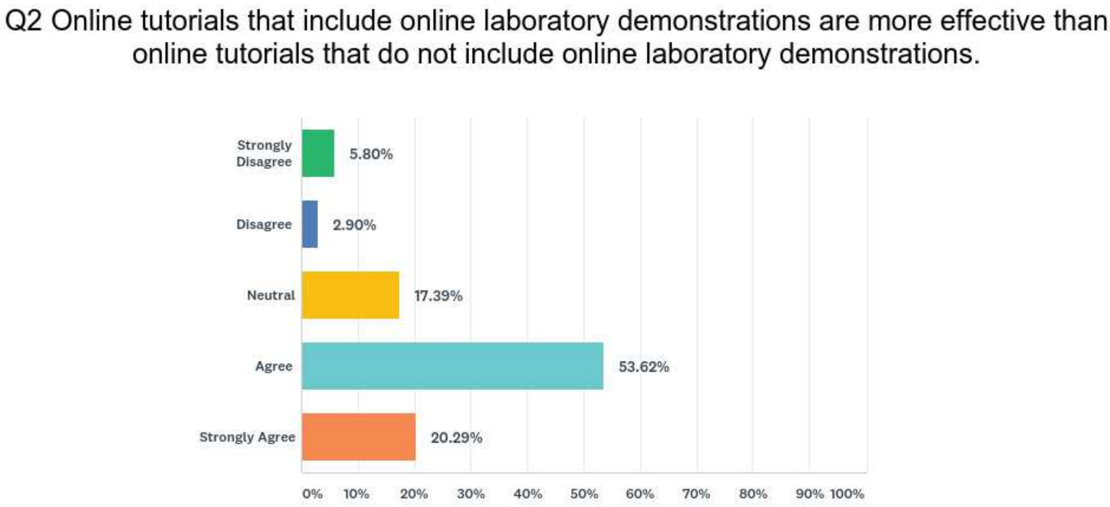

Figure 3b: Q2 Results of the survey for tutorial quality improvement.

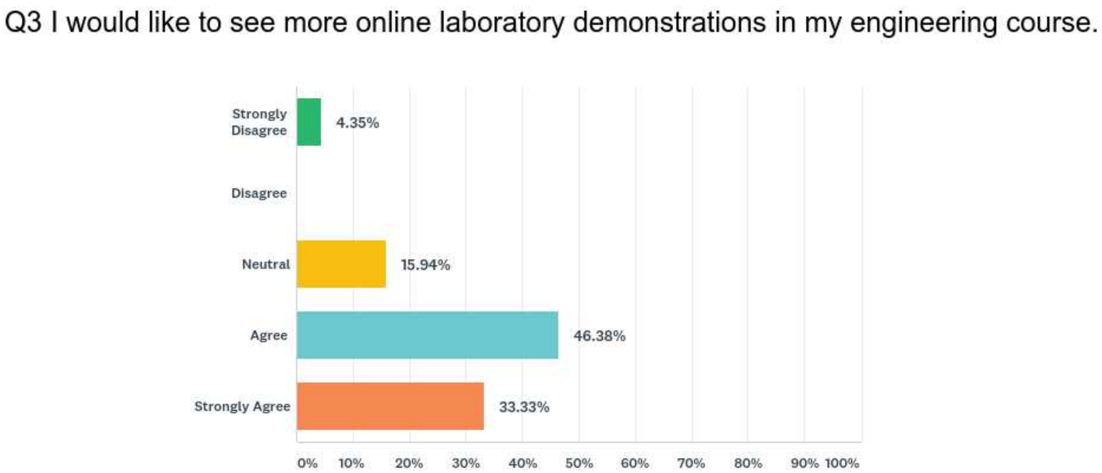

Figure 3c: Q3 Results of the survey for tutorial quality improvement.

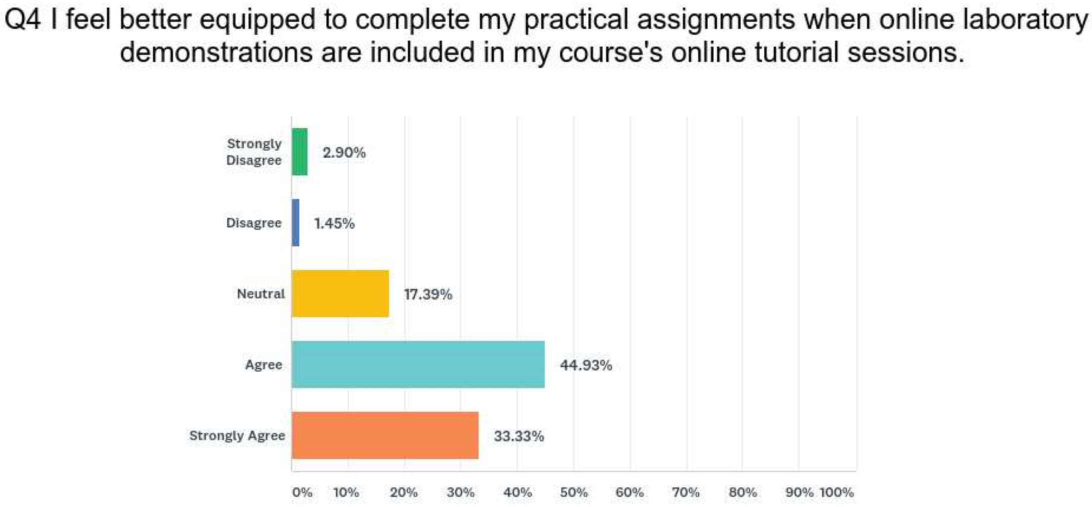

Figure 3d: Q4 Results of the survey for tutorial quality improvement.

Table 4: Table of survey result statistics including 95% confidence interval

Survey Questions	Survey Results		
	n	$\bar{x}$	σ
Q1	69	3.87±0.23	0.96
Q2	69	3.8±0.23	0.99
Q3	69	4.04±0.22	0.94
Q4	69	4.04±0.21	0.91

Discussion

Method 1

Factoring in the control unit; the difference in the average cohort grades between cycle 1 and cycle 2 was less than 0.4%, as depicted in Table 2, indicating a comparable and near-equivalent level of student ability. The p-value is 0.95 showing no significant difference in the ability between the 2015 and 2016 delivery cycles in the control group, thus students from each group are of a similar ability level.

When comparing the experimental unit grades between the two delivery cycles, there is a slight increase of 3% in grades for students who attended sessions with embedded online labs, in delivery cycle 2. What's interesting to note is that students performed better earlier in the course, most likely due to their confidence in using the lab for their assessment. Students without the embedded labs were left to their own devices in figuring out the labs, and this might have an impact on their earlier performance. The grades converge towards the end of the course and might indicate that students have all become more familiar with the labs due to continued use throughout the course. The p-value is 0.31 which suggests a not significant result at the 95% confidence interval, but given the scope of the study it warrants further investigation.

The grade data is also quite low ($n<100$) for a parametric test. The size of the cohort could influence the outcome, however, in the student surveys (also covered in this paper) for the unit with embedded lab demonstrations; students clearly highlight their perceived value in, and appreciation of, the inclusion of demonstrations for the practical parts of the work, where the unit without the demonstrations had no mention of this in the surveys - arguing that there was indeed a major impact when the labs were embedded. Additional limitations of the study include the limited number of trials as well as the variance between unit types and learning styles.

Method 2

The following was found when comparing the quiz results of Group A and Group B, detailed in Table 3:

- 27% of Group B had incorrect answers for both Q1 and Q2, as compared to only 7% of Group A. Focussing on Q1, which had identical delivery material between Groups, 79% of Group A had a correct answer, compared to 68% in Group B. This suggests an overall lower ability of Group B when delivered the same material.
- Despite this; 54% of Group B had a correct answer for Q2, as compared to only 50% of Group A. Using Q1 to scale relative expected performance; 79% of Group A were correct for Q1 and 50% for Q2.
- Given only 68% of Group B was correct in Q1, following the trend derived from Group A that would suggest an approximate 36.7% drop in correct responses from Q1 to Q2; Group B would be projected to have only 43% correct responses for Q2; yet they achieved 54% correct responses; 11% above the projection.

It would seem this increase in correct responses is due to the change in tutorial mode upon which Q2 is assessed. The limitations influencing this conclusion are however, many, including but not limited to the following considerations: technical differences in the delivery between groups contingent upon the individuals internet connection and hardware; the limited, diverse and asymmetric group sizes; the scale of the study; the method by which tutorial time was re-allocated to remote and virtual labs as well as the type of labs themselves; the types, nature and number of questions assessing tutorial content; ongoing and long-term assessment of group performance; the aptitude of the individuals for the subject; the learning style of individuals; as well as a need to swap the strategy and control group to further calibrate projected grades and determine causality.

Method 3

The survey presumes an equal likelihood of dissatisfied, impartial and satisfied students responding. The responses, detailed in Figures 3a, 3b, 3c and 3d, as well as the summary in Table 4, indicate a strong preference for embedded laboratories. 53.62% of responders agreed with the statement that online laboratories (software simulations or hardware with webcams) are effective in helping them to understand engineering topics, with a further 23.19% strongly agreeing, with a mean score of 3.87. 53.62% of responders agreed and 20.29% strongly agreed that online tutorials that include online laboratory demonstrations are more effective than online tutorials that do not include online laboratory demonstrations; as opposed to 2.9% disagreeing and 5.8% strongly disagreeing, with a mean score of 3.8. 46% agreed and 33.33% strongly agreed that they would like to see more online laboratory demonstrations in their engineering courses, with a mean score of 4.04, and 44.93% agree and 33.33% strongly agree that they feel better equipped to complete their practical assignments when online laboratory demonstrations are included in their course's online tutorial sessions, with a mean score of 4.04.

The responses indicate a perceived benefit to embedding online laboratories in tutorials, with over 73% of responses indicating perceived improvements to engagement and understanding. Although the standard deviations were all < 1 and the confidence intervals < 0.24, the survey data is also quite low (n<100) for a parametric test. The limitations of these results largely fall to: the diligence of the responder in accurately interpreting and answering the questions; the scale of the survey; and a link with demonstrable long and short term performance and understanding. Furthermore, all responders were international engineering students across several levels and disciplines, yet it was not tracked whether these aspects affect the responses, nor the fact that all of the students were undertaking engineering courses under an online delivery mode and blended delivery mode students were not considered.

Conclusions and Recommendations

From the three research methodologies employed, the paper observes that the use of remote and virtual labs during live online tutorial presentations improves the reaction of students and measurable learning outcomes. This strategy holds both a perceived improvement to engagement and relational learning, a reduction in uncertainty regarding online laboratories, as well as some evidence that it can yield net performance improvements across student cohorts when implemented effectively, verified by subsequent grade improvements. As with Tuysuz (2010) “it was identified as a result of this study that the use of virtual lab increased students’ achievement levels and made a positive impact on students’ attitude”. Future work should expand on the size of the study, the evaluation methodologies and the method by which labs are integrated into tutorials.

The general student feedback at EIT holds no shortage of open ended qualitative responses, asking for an even “greater use of labs” or praising “the interaction with labs” for contributing to a career-relevant “practical learning experience”; all points accentuated by the study conclusions contained herein. The recommendation is thus as such; that engineering educators may significantly enhance student engagement and relational learning by embedding remote and virtual laboratories into contextualized online or blended tutorial sessions, technical limitations notwithstanding. Future research will consider: larger sample sizes, the different types of labs and tutorials, and the degree of student-tutorial interactivity.

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Cultural Contexts of Learning Preferences: Relative Dominance of Self-Directed versus Other-Directed Learning Styles

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SESSION C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

CONTEXT Monash University is regarded as one of the top 25 internationalised universities in the world. As part of a curriculum redesign, Monash University's Faculty of Engineering recently introduced new multidisciplinary first year (FY) blended learning units that employ a mix of flipped, project-based, peer-to-peer, and traditional learning approaches. The present study focuses on one of these FY units with the aim of investigating the cross-cultural acceptance of the non-traditional pedagogies by students belonging to Asian and western campuses. Specifically, we present an international comparative study of the preferences for the various teaching/learning and assessment components within our selected unit by students in semester 2, 2016 on the Clayton (Australia) and Sunway (Malaysia) campuses.

PURPOSE The objective is to investigate if there are any culturally influenced preferences in relation to self-directed versus an expert-directed learning of the FY multidisciplinary blended learning unit.

APPROACH We carried out online surveys as well as focus group discussions involving students from both campuses towards the end of the semester. A five-point Likert scale was employed to capture the learning component preferences by students. The teaching/learning and assessment components included in the unit are: pre-class online videos, pre-class online textual material (called "e-publications" or "e-pubs"), pre-class quizzes, pre-practical class videos and quizzes, Moodle-hosted online discussion forum, in-class (supervised) problem worksheets, and in-class lecturer-led ("expert-led") sessions.

RESULTS The results suggest that the self-directed out-of-class teaching/learning components (pre-class lecture videos, quizzes, online discussion forum, etc) are *slightly* more preferred by the Clayton students. The Sunway students, on the other hand, showed slightly more liking for in-class guided problem solving and lecturer-led discussion of key concepts. The latter students also showed more preference for the detailed e-pubs. The most significant differences were found for pre-class videos (74% of Clayton students compared to 60% of Sunway students perceive them as enabling learning the content before the lecturer teaches/explains,) and in-class problems solving (72% of the Sunway students compared to 59% Clayton students see this as a way of enhancing their learning).

CONCLUSIONS Our study suggests that Malaysia based FY students show overall relatively lower preference for self-directed learning components compared to their Australia based counterparts. It must be emphasized that the number of students with Asian background studying engineering on the Clayton campus is considerable, yet there appears to be an increased preference for self-directed learning components amongst them. The present study sheds light on the intercultural aspects of innovative pedagogical methodologies and their global reach.

KEYWORDS Flipped classroom, blended learning, culture, learning preference.

Introduction

Globalisation of higher education is a growing phenomenon; the number of foreign university campuses has been steadily increasing in many countries, especially in countries considered as “education hubs”. Concurrently, the number of students carrying out education in foreign countries, commonly referred to as “international students”, is also on the rise and estimated to reach 7 million by 2020 (Altbach, Reisberg, and Rumbley 2009). The various implications and ramifications of such cross-border and transnational education ventures have been the subject of several publications (e.g., Lane, 2011; Knight, 2008; Lane et al., 2004; Skidmore and Longbottom, 2011; Waterval et al., 2017).

With globalisation of education comes the need to understand how well the curricula and pedagogies developed by a university for “native” students would be accepted by students in a foreign country doing the same education program. In engineering, obviously, it is impractical to have separate curricula and pedagogies for the originating country and target foreign country/countries. Consequently, if uniform cross-border education standards are sought within a successful and sustainable international education operation, the pedagogies used by the education provider must be compatible with the predominant teaching/learning preferences by students in all the countries involved.

Spurred on by the rapid developments in digital technologies, the past two-three decades have been witnessing a tremendous adaptation by universities across the world of blended teaching/learning methodologies as a means of providing innovative educational offerings (Friesen, 2012; Blended learning: a disruptive innovation). The blended learning approach calls for significant self-managed and self-directed learning by students. This could be particularly challenging for First Year (FY) undergraduate students coming with a secondary school training that utilises largely instructor-driven learning (Frambach et al., 2012). The cultural context also dictates student readiness for undertaking self-directed learning. In addition, the student learning styles and preferences shaped by cultural and ethnic dimensions can be of considerable importance, as shown by international comparative studies (e.g., Barron and Arcodia, 2002; Joy and Kolb, 2009; Holtbrugge and Mohr, 2010; Fang and Zhao, 2014; Budeva, Kehaiova, and Petkus, 2015).

As a leading education provider in the Asia-Pacific region Monash University will be keen for its education methodologies, largely developed in a western (Australian) context, to be acceptable to and embraced by students not only within Australia but also in foreign countries. The School of Engineering, Monash University Malaysia represents the largest engineering education operation under Monash University outside of Australia. The student population within the School of Engineering is largely Malaysian; however, approximately 25-30% of the students come from other countries in the region and typically include students from Middle Eastern and African countries as well. Thus “the Asian” or what may be termed “non-western” context should be an important consideration at Monash University in curriculum planning and redesigning. In an increasingly competitive tertiary education industry environment, changes made to education practice should not only reflect the emerging trends, but also lead to acceptance/uptake by large numbers of international students.

In this paper, we present a cross-border comparative study of the preference for self-directed versus other-directed teaching/learning components in a FY undergraduate multidisciplinary engineering unit offered by Monash University with the aim of investigating the relative cross-cultural acceptance of non-traditional pedagogies by students belonging to Asian and non-Asian campuses. Specifically, we present a comparative study of the preferences for the various teaching/learning and assessment components within the unit by students in semester 2, 2016 on the Clayton and Sunway campuses representing a predominantly “western” and “Asian” cultural context, respectively

Research Method

The present project forms part of a major study carried out on students doing two different FY multidisciplinary engineering blended learning units on the two campuses. The study presented here focused on the preferences by students on both campuses for various teaching/learning/assessment materials included in the unit. The teaching/learning and assessment components included are: pre-class videos, pre-class textual materials ("e-pubs"), pre-class quizzes, pre-practical class videos and quizzes, Moodle-hosted online discussion forum, in-class (supervised) problem worksheets, and in-class lecturer ("expert")-led sessions". It is to be mentioned that majority of the unit delivery aspects is the same on the two campuses. These include: (1) students from both campuses having access to the same teaching materials; (2) nearly identical assessments: pre-class quiz, class-participation quiz, pre-practical quiz, practical participation, laboratory work, projects demonstration and reports, and final examination; (3) the same amount of contact hours for the two cohorts; (4) the "experts" (lecturers) in the teaching team having similar expertise and backgrounds on both campuses. The only differences between the campuses are the background of the students taking this unit and, perhaps, the background of the teaching assistants.

Online surveys and focus group discussions in relation to students' preference/liking for the learning and assessment components were carried out on both campuses towards the end of Semester 2, 2016. Ethics clearance from Monash University Human Research Ethics Committee (MUHREC) was obtained prior to carrying out the survey and focus group. Consent form and explanatory statements approved by MUHREC were provided to each participant. The online survey and the focus group participation was on a voluntary basis.

The online survey instrument was designed using Google Forms and the responses were gathered through a 5-point Likert scale, ranging from *strongly agree* to *strongly disagree*. Questions asked in the online survey consist of items such as "*The pre-class videos on Moodle helped me to learn the course content even before the lecturer explained/discussed it in the expert-led session (ELS)*", "*The epubs on Moodle helped me to learn the course content even before the lecturer explained/discussed it in the ELS*," "*The pre-lecture online quizzes helped me to assess my learning progress*," "*I made efforts to learn the course content using resources other than that posted on Moodle*", and "*The problem sheet helped me with enhanced learning of the theory content*". In all, 78/515 students from Australia and 65/212 students from Malaysia participated in the study. Independent 2-sample *t*-test (a value of 0.294) and ANOVA (significance value of 0.702) suggested no significant differences student perception of self-directed (flipped) learning between the two campuses.

Semi-structured interviews were also conducted with randomly selected students who also participated in the online survey. The focus-group interview consisted of 7 students from the Malaysian cohort and 3 students from the Australian cohort. However, owing to the lack of coherency in the feedback in relation to the present topic (a result of the small number of participants from Australia), the focus group results are not discussed further.

Results and Conclusion

Figure 1 shows the cumulative responses to the question asking whether or not the students learned better with the flipped mode compared to the traditional mode. As the purpose of the present study was to determine the overall inclination of students to self-directed study (and not the degree of the preference) in the present analysis both "*agree*" and "*strongly agree*" responses have been combined. Similarly, both "*disagree*" and "*strongly disagree*" responses have also been combined.

It is clear that students from the "western" (Clayton) campus show relatively higher preference for the self-managed, self-directed (flipped) learning mode. The students from the

Asian (Sunway) campus are significantly more ambivalent in their preference for the self-directed, flipped learning mode compared to the traditional instructional mode of learning.

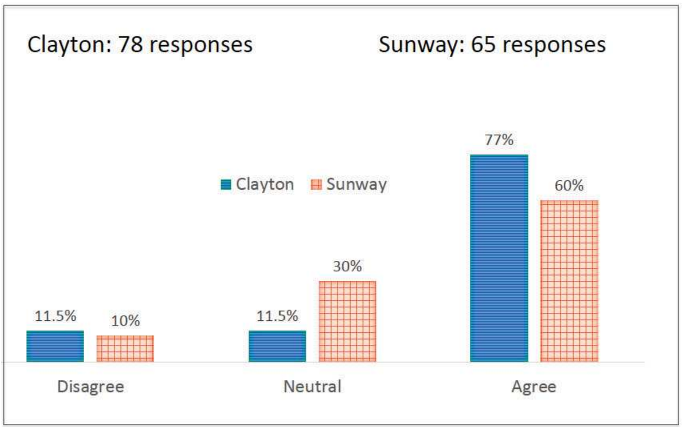

Figure 1: Cumulative student responses to preference for the flipped learning mode. Clayton students (solid bar) and Sunway students (cross hatched bar).

More insights can be gained by analysing the detailed student preferences for the various learning and assessment components employed in the unit (Figure 2). These components have been grouped into two categories: “self-directed” and “guided.” Learning using the self-directed components are managed entirely by students themselves in their own time whereas the guided components are supervised or directed by the lecturers concerned.

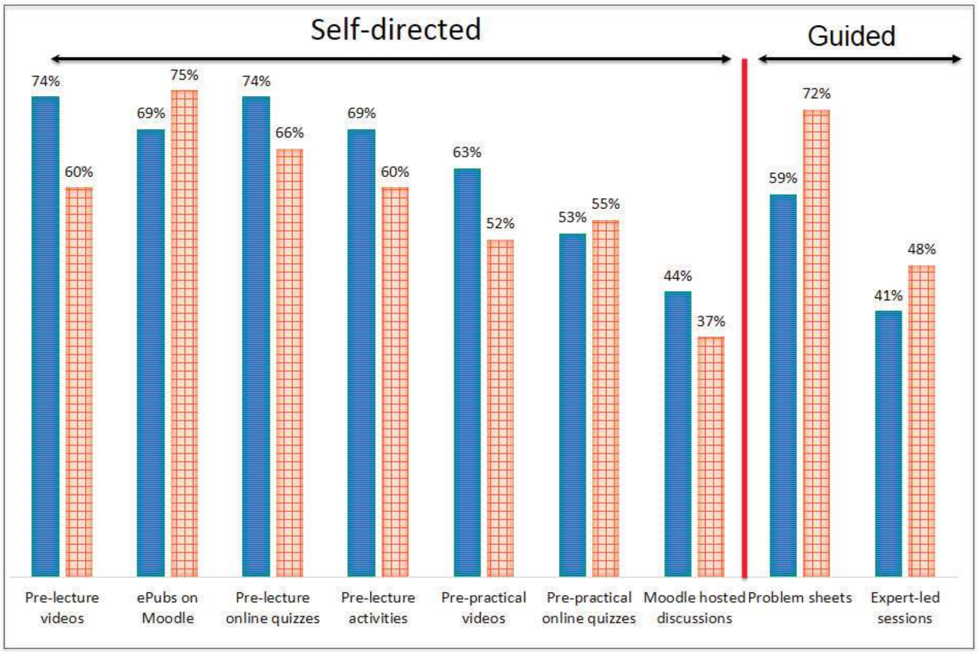

Figure 2: Student preferences for the various learning and assessment components embedded within the unit. Symbols as in Figure 1.

The online survey results suggest that the self-directed, out-of-class learning and assessment components (pre-class lecture videos, quiz, online discussion forum, etc) are slightly more preferred by the students doing their unit in a western environment (Clayton campus). The students representing the Asian cultural context (Sunway campus), on the other hand, showed slightly more liking for in-class guided problem solving and lecturer-led in-depth discussion of the key concepts. Students from the Asian context appear to have a higher preferences for examination-oriented learning activities such as the problem sheets and also would most likely to prefer a more face-to-face and physical interaction in the expert-led sessions compared to students in the western context, as observed in some other study also (Chen, 2014). The students from the Asian campus also showed slightly more preference for the detailed e-pubs, possibly reflecting their relatively more dependence on "delivered" content than own "researched" content.

The most significant differences were found for pre-class videos (74% of Clayton students perceive it as helping them learn the content on their own before the lecturer teaches/explains, compared to 60% of Sunway students) and in-class worksheet based problems solving (72% of the Sunway students compared to 59% Clayton students see this as a way of enhancing their learning). A striking aspect of the results is the relatively lower student interest (from both campuses) in the online discussion forum (intended to facilitate peer-to-peer sharing of learning) and lecturer-led sessions intended for in-depth and "big picture" discussions. Empirically, we have observed a significant "spike" in online discussion immediately prior to the final examination, particularly originating from students based on the Clayton campus discussing the concepts in great depth; the Sunway students have been thus far relatively less enthusiastic about such online discussions and keener to consult lecturers in person. It is clear that although flipped/blended learning approach is designed to facilitate just-in-time learning, there is a considerable amount of "catch up" learning occurring towards the end of the semester. Interestingly, we have observed that the learning preferences displayed by students on the two campuses do not translate to significantly different "learning outcomes" achieved by students as measured by their grades.

From the foregoing discussion of self-directed versus other-directed learning behaviours of students representing predominantly western and Asian cultural contexts it is clear that there is a significant, albeit small, underpinning cultural bias in relation to student readiness for self-directed learning. The Asian students have a higher preference for guided learning activities. This is particularly important in relation to one of the necessary engineering learning outcomes for undergraduate students as stipulated by the International Engineering Alliance (Washington Accord): life-long learning skills development by the students. It is also clear that despite such learning preference differences students from both cultures are able to adapt and perform equal well.

A number of questions arise from the above discussion. How much independent learning can students achieve when situated in different cultures? To what degree the pre-university education shapes the students' readiness to successfully embrace self-directed learning in their tertiary education? Do factors such as English proficiency and cultural conditioning play a part in determining students' ability to learn using the emerging pedagogical innovations? It would also be worth carrying out an in-depth study of the learning preferences of domestic versus foreign students in a "western" campus.

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An Engineering Approach to Engineering Curriculum Design

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CONTEXT

The School of Electrical and Electronic Engineering at the University of Adelaide has for many years been offering a range of Electrical and Electronic Engineering degrees in several specialisations. By 2013 a range of external factors had combined to motivate a major review of the curriculum for all of these qualifications

PURPOSE

There were several drivers for the review, including: the need to ensure AQF level 8 compliance; changes to University policies since the previous revision; and recommendations from internal reviews and accreditation processes. The primary motivation however was to refresh the technical content of the program and to ensure that learning outcomes are aligned to Engineers Australia Stage 1 Competency standards, the evolving needs of employers, and research education outcomes.

APPROACH

Once the need for a major curriculum revision had been established, the challenge was to achieve a School-wide transformation in mindset, from the entrenched content-based approach to a pervasive outcomes-oriented approach. We describe the process we used to achieve this transformation through a structured top-down design approach, maintaining clear traceability to the objectives of the review. The working group leading the curriculum review was encouraged to 'think like engineers' by first considering the project specifications (i.e., the skill and competency profile that we wanted to achieve for the Adelaide Electrical and Electronic Engineering graduate), and then applying design principles and a systems perspective to the task at hand.

RESULTS

The new curriculum commenced operation for the first time in 2016. The new curriculum is more coherent and better focussed than the previous version, offering more flexibility to students in choosing their preferred area of specialisation. Feedback indicated that we did not achieve all of our learning and student engagement objectives in the first year courses, so the pedagogy has been reviewed and fine-tuned for the 2017 delivery.

CONCLUSIONS

At this stage of implementation of the new program we are confident that the new curriculum is working well, providing more flexibility for students and showing a clearer alignment to defined learning outcomes. We expect that by the end of the year we will have sufficient feedback from students to ascertain whether we have improved the student experience and program coherence from their point of view.

KEYWORDS

Curriculum renewal; outcomes-based design; systems approach; curriculum design principles; constructive alignment.

Introduction

The School of Electrical and Electronic Engineering (The School) at the University of Adelaide has offered degrees in electrical engineering since 1946. Following developments in the discipline, the original electrical engineering degree was renamed Electrical and Electronic Engineering in the 1980s and was later expanded to add a family of named degrees in Computer Systems Engineering, Telecommunications Engineering, and Electrical and Sustainable Energy Engineering, all based on a common mathematics, fundamental science and electrical engineering science core. Throughout this evolution the School has balanced the introduction of new technologies with the displacement from the curriculum of fundamental science, but without a systematic review of pedagogy or program objectives.

By 2013 the School had become sensitised to the need to undertake a substantial curriculum review because the pressures to introduce new technology content could no longer be managed by this process of displacement. It was clear that a considered re-evaluation of what is the essential knowledge for an electrical and electronic engineering graduate would be necessary to produce a new program that could form the basis of education in the discipline over the next decade or more. At the same time the School was dealing with a relatively flat demand for the degree by school leavers, following the collapse in demand for ICT-oriented programs in the early 2000s.

External pressures were another significant driver for comprehensive change. New provisions in University policy required additional generic content in all programs, most significantly the inclusion of non-cognate elective options. The University also required explicit curriculum structures to meet the AQF criteria for Level 8 Bachelor (Hons) degrees. Successive Engineers Australia (EA) accreditation reports urged embedding professional competencies throughout the program. Importantly, it was also becoming clear that specialised named degrees were declining in popularity as, in the tight post-GFC employment market, students were looking for more generic and portable qualifications.

It was clear, given the multiplicity of constraints that would have to be satisfied, that some difficult compromises would be required and that we would need a robust set of criteria for making these compromises. Meeting all these demands would be difficult to accommodate with incremental changes to the existing structure.

Against this background the School resolved to undertake a comprehensive ground-up redesign of its undergraduate engineering programs – probably the most extensive change to the program in its history. Serendipitously, this coincided with a University-wide project to introduce a whole of program curriculum development approach (Curriculum Renewal), enabling access to curriculum design support.

At the outset, we committed to focusing on the graduate outcomes of the program, viewing all current content in the program as being potentially disposable. This was a substantial change of philosophy for what had long been a content-focussed curriculum. The University sponsored Curriculum Renewal approach was grounded in Constructive Alignment principles promoted by Australian education researchers (Biggs & Tang 2007; Oliver 2011; Lawson 2014). These approaches did not, however, take a discipline focussed approach, e.g. ‘thinking like engineers’ for engineering curriculum or ‘thinking like managers’ for management curriculum. Nor did they consider the integrated and complex relationships between progression across the degree and learning outcomes at the course level and at the degree level. They did, though, consider development of professionally relevant competencies in some cases.

Project Curriculum Design Conceptualisation

The task of developing a proposal for a revised curriculum was placed in the hands of a curriculum design team comprising the authors – academics in the School of Electrical and Electronic Engineering and a curriculum design specialist (Eglinton Warner) who was assigned to the project by the Deputy Vice-Chancellor (Academic)’s office as part of the Curriculum Renewal project. The academics on this team were selected for pragmatic reasons as well as for their interest in the proposed work. This team represented a range of sub-disciplines within electrical and electronic engineering and teaching expertise at each year level within the degree. They were also a team small enough to be able to make time to engage in the deep and robust exploration of issues and ideas within the relatively short timeframe set by the University to demonstrate outcomes from the Curriculum Renewal project. It was always intended that this team, at the conclusion of the University sponsored project, would become a critical core who would then continue the work by engaging with and building capability of colleagues throughout the School and the other engineering schools within the Faculty.

The University's Curriculum Renewal approach, grounded in Constructive Alignment (Biggs & Tang 2007) conceives degrees and their courses as a system. In this system the learning intentions at the degree level (Program Learning Outcomes) are achieved by the integrated and aligned interactions of the learning intentions at the course level (Course Learning Outcomes), developed through the learning activities and confirmed through the assessments. Collectively the course assessments provide evidence of the progress towards and achievement of the Program Learning Outcomes (Baume 2009). Applying this in the context of engineering the work of the team was also influenced by work done at MIT (Crawley 2001; Crawley, Malmqvist, Lucas & Brodeur 2011) using a multiple perspectives and whole of degree approach to inclusion of professional as well as technical skills in engineering degrees. It was also influenced by Toral, Martınez-Torres, Barrero, Gallardo & Duran (2007) and Cornwell (1996) who used concept mapping to inform curriculum design. Design principles (Lidwell, Holden & Butler 2003) were also considered when developing a conceptual framework within which to operate. Based on initial review of available literature at the time, combining these approaches and conceptualising curriculum design as an engineering problem had not yet been applied in practice in Australia.

For this engineering problem (i.e. curriculum design) the required outputs in the form of graduate outcomes were known (or at least would be agreed on by the stakeholders), the raw materials and the external constraints were given, so the problem reduced to determining a process to achieve the required outputs subject to these constraints – a standard engineering design process. Framing the problem at hand as a need to achieve certain outcomes subject to numerous non-negotiable constraints was key to securing acceptance of the idea that a completely new program design would be necessary and that it was inevitable that some of the existing program content would be discarded – at least from the program core.

The team executed the project by following the decomposition and definition stages captured in the left hand side of the well-known system engineering V diagram (Forsberg and Mooz, 1991). The integration and verification process on the right hand side of the V diagram is being executed as a combination of outcomes mapping processes and progressive course implementation. We will discuss this stage of the process in more detail towards the end of this paper.

Decomposition and Definition

Program Learning Outcomes and Technical Skills Profile

We conceptualised the User Requirements for our system as being a combination of the Program Learning Outcomes (PLOs) and the Technical Skills Profile (TSP) that should be developed in our graduates. The PLOs were adapted from the outcomes that had been developed in the process of revising the programs for AQF Level 8 compliance in 2015. They strongly reflected the Engineers Australia Stage 1 Professional Competency Standard (Engineers Australia, 2013) and the mandated University Graduate Attributes. Consequently, the PLOs were largely focussed on generic professional and engineering competencies and provided little detail about specific technical and scientific knowledge and application abilities of graduates. The team was of the view that our PLOs would be unlikely to be very different from those of many other electrical and electronic engineering programs accredited by EA. On the other hand, the School did have a firm view that its graduates would be distinguished by their profile of mathematical abilities, scientific knowledge and breadth of exposure to electrical engineering science. The TSP was therefore considered to be an essential part of the output specification for our graduates. We agreed, early on, that our graduates should be characterised by a broad knowledge of the fundamental principles and technologies, with a strong foundation in the underpinning mathematics and (to a lesser extent) science.

Arriving at an agreed technical skills profile was perhaps the most contentious step in the process. We used a mapping process to capture the views of those in the working group on what is essential, desirable or optional knowledge for our graduates. We began by brainstorming to identify all of the areas of knowledge that might reasonably be considered for inclusion in the new curriculum. These views were unquestionably influenced by the areas of technical expertise of the individuals in the group, but because the team represented the broad range of specialisations within the School, a wide range of views and perspectives was captured. The group was large enough to be representative, but small enough to reach consensus in a pragmatic way. We initially constructed a table of skill sets that each member of the initial design team considered to be essential, desirable or neither for graduates on each specialisation. A section of this table is shown in Table 1.

Table 1: Initial Assessment of Content (partial map shown)

E = Essential D = Desirable *_ if neither*	B Eng (EE)	Energy Specialisation	Telecommunications Specialisation	Computer Engineering Specialisation
Science				
• Newtonian mechanics - linear and rotational	EEEEE	E_EEE	E__EE	E_DEE
• electromagnetics	EEEEE	E_EEE	E_DEE	E_DEE
• electrostatics	EEEEE	E_EEE	E_DEE	EEDEE
• solid state physics	EDEDD	E_DD_	E_DD_	EDEDD
• relativity - quantum mechanics	D_D__	__D__	_____	_____
• optics	D_DD_	___D_	D_DD_	D__D_
• material properties	D_DDD	D_DEE	___DD	___ED
• thermodynamics	D_DED	E_EEE	D__DD	D__DD
• biology	D_DD_	___D_	___D_	___D_
• chemistry	D_DD_	D_DD_	D__D_	D_DD_
• psychology	D_D__	D_D__	D_D__	D_D__
• philosophy & logic	D_D__	D____	D_D__	D____
Energy				
• machines	EEEEE	E_EEE	___DD	D_DDD
• power electronics	EEEEE	E_EEE	____D	D_D_D
• power systems	EEEEE	E_EEE	D___D	D_D_D
• energy sources	EDDEE	E_EEE	D__DD	D_DDD

Table 2: Theme Map (partial map shown)

THEMES	RELEVANCE				BREADTH x DEPTH				TIMING
PROGRAMS	EEE	Energy	Tele	Comp	EEE	Energy	Tele	Comp	
1. Software and Programming	A	C	A	A	b d	- d	B d	B d	E
2. Energy processing *(conversion and transportation)*	B	A	C	C	B d	B D	b -	b -	V
3. Communication Networks *(topology, dimensioning, protocols, systems and standards)*	B	B	A	B	b -	b -	B d	b -	L
4. Signal Processing *(discrete and continuous time)*	A	B	A	B	B d	b d	B d	b d	M
5. Practical Electrotechnology *(solder, assemble, PCB, components)*	B	B	C	B	b d	b d	b -	b d	E
6. Systems Engineering *(entire lifecycle - design, standards, requirements - holistic view, interactions, unique language & methodologies)*	A	A	A	A	b d	b d	b D	b d	V

Themes

After discussion and debate based on the level of support that different topics received in this initial matrix, the topics were refined and aggregated into themes. Themes were classified according to their level of importance to each specialisation expressed in the first map. The group then debated and agreed upon the level, breadth and depth of coverage of each theme on each specialisation and the approximate position of the coverage on the program – early, middle or late. Table 2 shows a section of the themes map. The importance of each theme is coded as A, B, or C in the left hand section of the table. On the right the extent of breadth and depth of coverage agreed for each theme is indicated by a capital B/D, lower case b/d or a hyphen -. The approximate location on the curriculum is indicated in the last column by E, M or L for early, middle or late. A "V" in this column indicates that a theme should be pervasive throughout the curriculum. Finally, a theme is shaded for a specialisation if it is a distinctive theme for that specialisation. Dark purple shading in the case of Systems Engineering indicates that the theme is intended to be a distinguishing characteristic of all versions of the program.

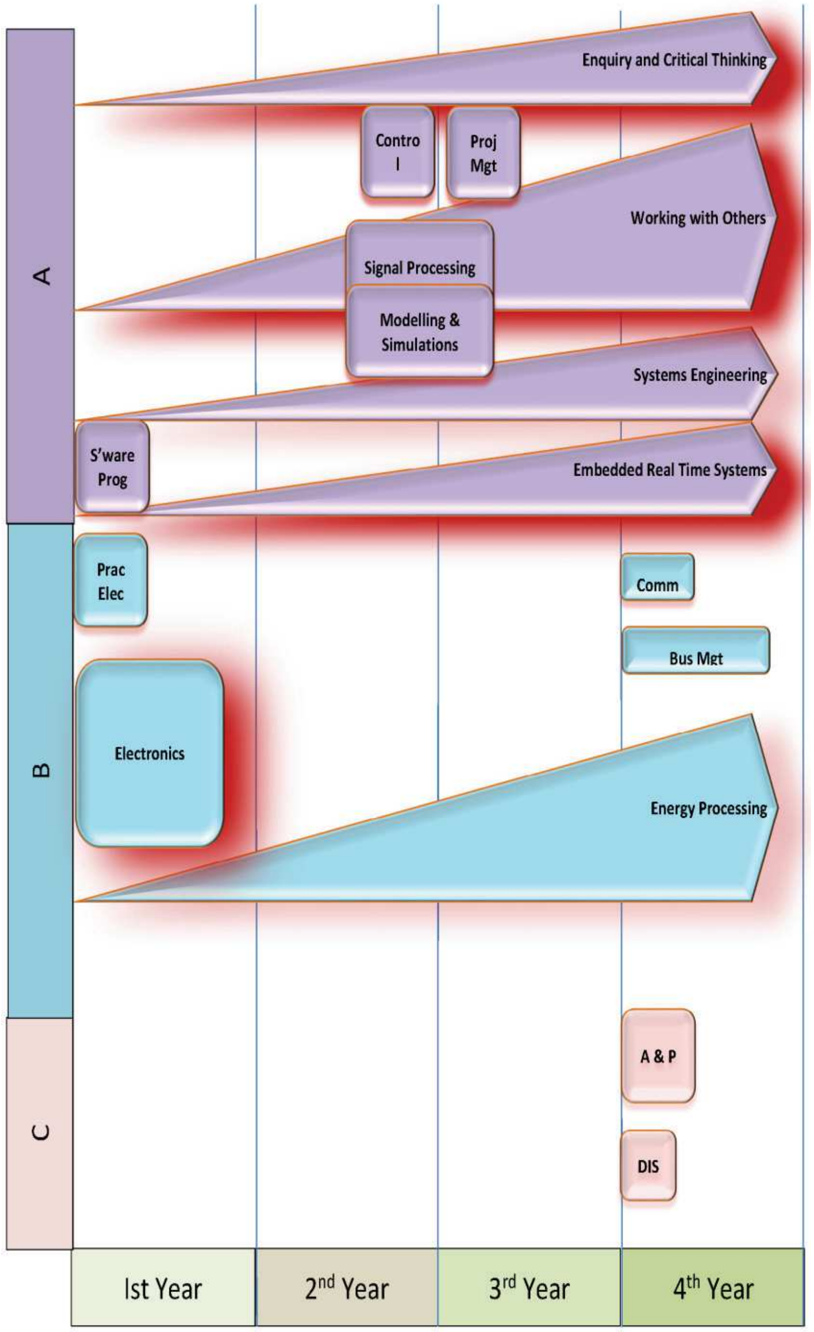

Figure 1: Dimensioning and Positioning Themes

As a final graphic aid to understanding the emphasis and trade-offs in each version of the program, the information contained in the themes map was translated into a graphic showing the timing, breadth and depth of each theme. We experimented with several graphical representations of the space each theme would occupy in the different versions of the program, eventually settling on the form shown in Figure 1. The size of each object in this diagram is meant to indicate breadth, and the intensity of the shadow its depth. A thickening object indicates progressive development over two or more years.

The next step was to rationalise the content by compressing the various sized and shaped themes into the four-year duration of each program. This was a stage involving many compromises, but we deliberately kept discussion at a high conceptual level, allowing us to make decisions based on high-level learning outcomes rather than attachment to specific content. A snap shot of this result is shown in Figure 2.

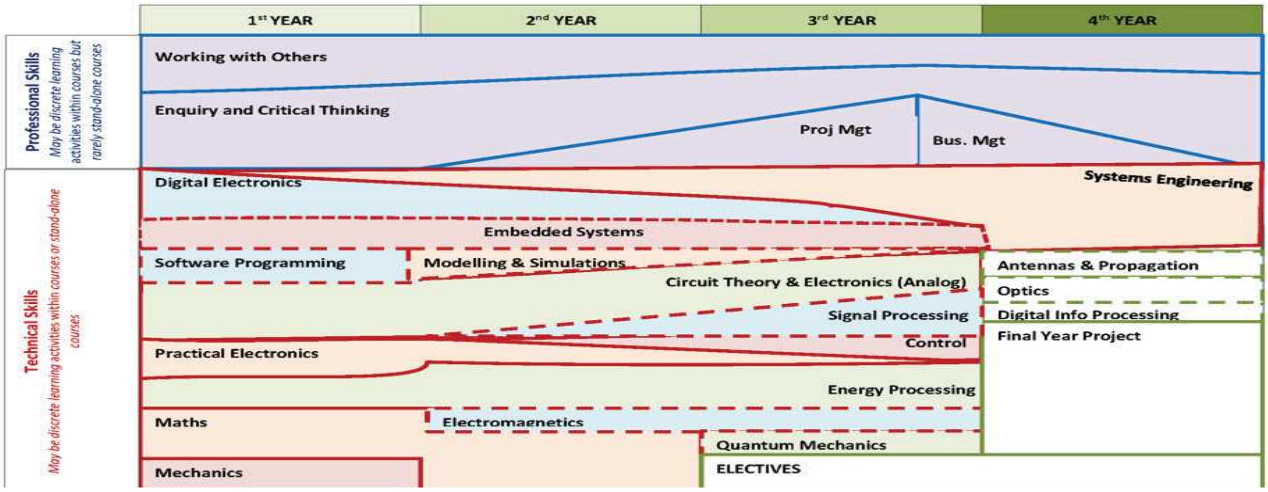

Figure 2: Distribution of Broadly Defined Knowledge and Competencies across the Degree

Courses

Themes were then divided into courses, forcing further compromises as minor topics were merged and larger topics were rounded up or down to fit standard course sizes. This resulted in the more conventional 4x8 course map shown in Figure 3. There was a deliberate attempt to keep course titles aligned to themes, rather than reflecting specific content. Different coloured shading reflects different themes.

YEAR 1	YEAR 2	YEAR 3	YEAR 4
MATHS I	MATHS II	Specialist topic	RESEARCH PROJECT
		SIGNAL PROCESSING AND CONTROL	
CIRCUITS AND ELECTRONICS A	CIRCUITS AND ELECTRONICS B	CIRCUITS AND ELECTRONICS C	
DIGITAL ELECTRONICS AND EMBEDDED SYSTEMS A	DIGITAL ELECTRONICS AND EMBEDDED SYSTEMS B	DIGITAL ELECTRONICS AND EMBEDDED SYSTEMS C	BUSINESS MANAGEMENT
ENERGY A	ENERGY B	ENERGY C	Specialist Topic
SOFTWARE PROGRAMMING	MODELLING AND SIMULATIONS	PROJECT MANAGEMENT	Specialist Topic
PRACTICAL ELECTROTECHNOLOGY*	SYSTEMS ENGINEERING A	SYSTEMS ENGINEERING B	SYSTEMS ENGINEERING C
MECHANICS	ELECTROMAGNETICS	QUANTUM MECHANICS	Specialist Topic

Figure 3: Preliminary Course Map

Then individual course design commenced, identifying course learning outcomes and titles. We recognised the danger of losing alignment to program learning outcomes at this stage so we tabulated each course with its learning outcomes under the theme of which it was part and ensured that the progressive development of Course Learning Outcomes within a theme aligned to the technical and/or professional learning outcomes that they were designed to serve. Toward the end of this task, we decided to implement each specialisation as a major within the Electrical and Electronic Engineering program. Figure 4 shows an extract from the early mapping under Majors. While this added a further constraint, as we committed to keeping the core of the program common in the first two years, enabling students to choose their major at the start of third year proved to be one that was relatively easy to accommodate because of the earlier decision we had made about the positioning of foundational topics in the early part of the program.

		BE(HONS)EE PROGRAM LEARNING	ELECTRICAL AND ELECTRONIC MAJOR	ELECTRICAL SUSTAINABILITY ENERGY MAJOR	T
		By the end of the Bachelor of Engineering (Honours) (Electrical and Electronic) program Graduates will...	*To develop and apply the skills and knowledge to develop and design electrical and electronic devices, machines and systems suitable for a range of applications*	*To develop and apply the skills and knowledge to develop and design high performance and low cost renewable energy systems*	*T c r*
KNOWLEDGE	1	Have knowledge of the comprehensive theory underpinning natural and physical sciences and the engineering fundamentals applicable to the electrical and electronic engineering discipline	Principles of Electronic Systems Foundations in Digital Systems Introduction to Programming for Engineers Introduction to Electrical Engineering Analysis and Application of Electronic Circuits Digital Systems Electric Energy Conversion Object-Oriented Programming for Engineers Control Digital Signal Processing	Principles of Electronic Systems Foundations in Digital Systems Introduction to Programming for Engineers Introduction to Electrical Engineering Analysis and Application of Electronic Circuits Digital Systems Electric Energy Conversion Object-Oriented Programming for Engineers Control Digital Signal Processing	P F I I A D E O C D
SKILLS & APPLICATION	5	Be able to think critically, and to apply logic and exercise judgement, in analysis, design and decision making in contexts relevant to electrical and electronic engineering	Introduction to Electrical Engineering Systems Engineering A Systems Engineering B Project Management Business Management Systems Electrical and Electronic Research Project Principles of Electronic Systems Foundations in Digital Systems Analysis and Application of Electronic Circuits Digital Systems	Introduction to Electrical Engineering Systems Engineering A Systems Engineering B Project Management Business Management Systems Electrical Sustainable Energy Research Project Principles of Electronic Systems Foundations in Digital Systems Analysis and Application of Electronic Circuits Digital Systems	I S S P B T P F A D
	7	Be able to apply their	Introduction to Electrical Engineering	Introduction to Electrical Engineering	I

Figure 4: Mapping against Majors

Integration and Verification

The program design was completed and approved in 2014 and introduced for students commencing in 2016. To manage the workload of implementing such a comprehensive curriculum review we are implementing the new course year by year. We are currently in the process of teaching the first year of the program for the second time and the first offering of the new second year, so we are in the relatively early stages of integration and verification. In the system engineering language of Forsberg (Forsberg and Mooz, 1991) our courses are the configuration items and we have so far designed and implemented two at level 1, four at level 2 and are in the process of designing the level 3 courses. In all cases the courses have been designed to the Course Learning Outcomes specified in the Decomposition and Definition stage.

The development of courses has involved the initial design team consulting and collaborating with, advising and supporting colleagues. They have used their deeper understanding of the processes, underpinning theories and justifications of the design developed through the initial Curriculum Renewal project to build understanding and ‘buy-in’ of colleagues. This was integral for the longer term plans of the School (i.e. beyond the initial 9 month project) as it was assumed that successful implementation required the informed consent and engagement of academics within the School and other engineering schools within the Faculty.

Verification of the full system design will of course not be possible until our first graduates emerge at the end of 2019 when we will solicit feedback from both graduates and employers. In the meantime we are verifying the outcomes of individual courses using the usual indicators: student satisfaction rates, pass rates and average marks. We also completed a retrospective map of the course learning outcome and assessment activities to program learning outcomes, EA Stage 1 Competencies and University graduate attributes, as part of preparation for a regular accreditation review in 2017. The approach taken to curriculum mapping, grounded in Constructive Alignment principles, using common tools (e.g. MS Excel) to represent complex relationships, has allowed the integrity of the degree as a whole to be visualised, analysed and evaluated. Review of all this data has validated our design.

Feedback from students on individual courses has been variable. In particular it is clear that we have attempted to cover too much ground in the first attempt at one of the first year courses and we are making changes to that (with consequent changes to one of the level 2 courses).

Conclusion

We believe that with this approach to curriculum design we achieved a fundamental change in the philosophy of engineering curriculum design within our institution. The focus on program learning outcomes and technical skills profile as the output of our programs has relieved us from the debilitating focus on content. The traceability of course learning outcomes and course design and implementation to program requirements, through a conventional engineering decomposition and definition process, has been crucial in securing both buy-in and support from our academic colleagues and University-level approvals for the curriculum. It will also be the key to adapting the program as we proceed with the integration and verification phase over the next two years: adapting course design to respond to observed student learning outcomes and to student and employer feedback. By ensuring all elements in the degree (timing, depth, breadth, content, program and course learning outcomes, assessment and learning activities) are explicitly aligned and monitored by the curriculum mapping and review processes, any future changes and refinements can be tracked and considered to ensure the integrity of the system is maintained.

It was expected that a comprehensive curriculum revision like this was going to challenge some long held views about the primacy of content in an engineering curriculum. On reflection, we could have beneficially engaged with a broader group of colleagues at the outset, particularly in defining the technical skills profile. Nevertheless, by adopting an engineering design approach we have been able to completely justify our proposed changes by demonstrating that the design can be traced back to agreed outcomes specifications. Furthermore, the proposed approach is applicable to other engineering curriculum design and nothing prevents its utilisation in other disciplines. Indeed this project has been used as an example of effective curriculum review and design practices by the education specialist on the team, with other Schools and Faculties across the University.

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Attitudes Towards Software Engineering Education in the New Zealand Industry

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SESSION C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

CONTEXT Software Engineering (SE) is one of the newest engineering disciplines, and the ideal structure for an SE programme is not yet well understood. The purpose of this study was to obtain feedback on topics that should be covered in an SE degree from Alumni of our SE degree and local professionals working in the SE industry involved in hiring decisions.

PURPOSE We wanted to identify what we are doing well in our current programme, what is valued by industry, and what new areas to include or improve. Our findings can be used by other SE programmes as they update their cirriculum. We also wished to investigate whether there was a perceived value in SE being a four-year engineering degree and what the perceived differences were with a three-year Computer Science (CS) degree.

APPROACH We created two online surveys to get feedback on our SE programme, one for SE Alumni and one for local SE professionals. The surveys, included Likert scale and open-ended questions. Respondents rated the importance of multiple SE-related skills and the ability of local SE professionals in those skills. Respondents also provided their opinions on various aspects of our SE degree.

RESULTS We got responses from 28 Alumni and 22 professionals from the local SE industry. The results provide a ranked list of 37 skills deemed important for SE graduates, which can be used to identify gaps in existing SE programmes. The skills ranked most important were “Working in a team”, “Communication skills” and “Solving problems in a team”. We also compared the differences between the importance of a given skill and the actual ability of SE professionals for that skill as rated by SE managers. The largest gaps were software quality, software testing, software design, communication skills and solving problems in a team.

We also found that the majority of respondents (20 of 26 or 76.9% of Alumni and 11 of 15 or 73.3% of industry respondents) believe there is a difference between the graduates of an SE program compared to a CS program. Most respondents believe that there are unique benefits for each degree and that the degrees complement each other.

CONCLUSIONS Soft skills are critical skills in SE and make up seven of the top eight most important skills. Two soft skills, communication skills and solving problems in teams, were in the top five gaps in current SE programs identified by SE hiring managers. Other areas where SE programs could improve include strengthening the software quality, design and testing skills of graduates. We also found that industry perceives a difference between a SE and a CS graduate, and that both are needed in the software industry.

KEYWORDS Software Engineering, Software Industry, Curriculum

Introduction

Software Engineering (SE) is one of the newest engineering disciplines. For many years, SE was taught as one or two papers in a Computer Science (CS) degree, but recently emerged as an Engineering program in its own right. Previous research found a large mismatch between SE education and industry needs (Leibenberg et al. 2015), and despite initiatives to define a core body of knowledge for SE there remains confusion about what distinguishes SE and CS programmes (see, for example, Landwehr et al. 2017). Thus, the ideal structure for an SE programme is still not yet well understood. SE was introduced at the University of Auckland (UoA) in 2000, with the first graduates in 2003. It has successfully undergone three accreditation processes, the last being in 2015. However, there has been no formal review on how the Software Industry views the degree. The purpose of this study was to obtain feedback on topics that should be covered in an SE degree from UoA SE Alumni and local professionals working in the SE industry involved in hiring decisions for SE-related positions.

The SE program at the UoA is about to undergo a major curriculum review. We wanted to identify what we are doing well in our current programme, what is valued by industry, and what new areas to include or improve. We also wished to investigate whether there was a perceived value in SE being a four-year engineering degree and what the perceived differences were with the three-year CS degree, also offered at the UoA.

Related Work

The term "Software Engineering" has been around since the late 1960s (Landwehr et al. 2017, Parnas 1999), yet its precise definition remains unclear. Parnas (2011) calls SE a discipline that is missing in action. The term was used as a euphemism for "programmer" in job advertisements (Parnas 1999), and the difference between these terms is often unclear even today (Landwehr et al. 2017). The term is also used interchangeably with Software developer (Tookey 2015). Tookey (2015) argues this is to the detriment of the software development profession, because hiring managers focus more on skills related to learnable technologies, rather than focusing on broader SE skills; this is ultimately having an impact on the quality of software products produced.

The ambiguity in the definition also impacts on how SE is taught. There have been a number of efforts to define a core body of knowledge for SE. The *Software Engineering Body of Knowledge* (SWEBOK)[1] is an IEEE Computer Society publication which identifies 15 knowledge areas: requirements, design, construction, testing, maintenance, configuration management, engineering management, engineering process, methods, quality, professional practise, engineering economics, computer foundations, mathematical foundations, and engineering foundations. It was first published in 2004 and is now up to its third version. SWEBOK was intended as a guide to what skills a SE graduate should have after 4 years of training. However, it covers only material that is specific to SE. The *Curriculum guideline for Undergraduate Degree Programs in Software Engineering* (SE2014)[2] is another IEEE Computer Society publication, which is similar to SWEBOK, but it is specifically aimed at undergraduate program development and also includes material not specific to SE that is necessary for professional engineering training, including mathematical and engineering fundamentals and professional practice skills. Its first version was also published in 2004, and a revised version came out in early 2015. SE2014 identifies 10 knowledge areas: Computing essentials, maths and engineering foundations, professional practise, software modelling and analysis, requirements analysis and specification, software verification and

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[1] https://www.computer.org/web/swebok
[2] http://www.securriculum.org/SE2014FinalVersion.pdf

validation, software process, software quality, and security (Ardis 2015). There is a large amount of consensus in the skills required for SE in the two documents, although the knowledge areas are organised differently (Tookey 2015).

There is also literature available on curricula for specific SE programmes using the above principles (e.g. Frezza et al. 2006, Karaunasekera and Bedse 2006, Ramakrishnan 2007, Alarifi et al. 2014, Camilloni et al. 2015). However, Landwehr et al. (2017) argue that instead of looking at curricula and knowledge areas it is better to look at capabilities required for a software engineer to be able to develop products. They note that there is a difference between how science and engineering programs present the bodies of knowledge in SE. The former teaches students how to verify and extend that knowledge; the latter teaches students how to apply that knowledge when developing products. They also argue that the associated body of knowledge will grow quickly in SE, but the capabilities required for software engineers are the fundamentals and will be slow to change. Yet, Moreno et al. (2012) argue there are still gaps between what industry wants and the skill set of the graduates.

The original motivation for *Curriculum guideline for Undergraduate Degree Programs in Software Engineering* SE2004 (SE2014's predecessor) was a survey of 200 participants in the US software industry (Lethbridge 2000). Participants were asked for feedback on 75 education subject areas. The topics were determined by studying typical university curricula in computer science and computer engineering (Lethbridge 2000). The results suggested the need for a new curriculum, which ultimately gave rise to SE2004. To investigate the universality of the industry needs, industry in other countries have also been assessed using the same set of criteria, such as Britain (Kitchenham et al. 2005), Finland (Surakka 2007) and South Africa (Liebenberg et al. 2015). However, these studies used out-dated subject criteria (based on Lethbridge (2000)) and focused only on the technical skills (e.g. databases, programming) and did not include soft skills. Aasheim et al. (2009, 2012) surveyed the US industry with their own set of criteria that included both soft skills and technical skills. In both of their studies, the top 10 skills were the same: honesty and integrity, attitude, willingness to learn new skills, communication skills (written and oral), analytic skills, professionalism, ability to work in teams, flexibility, motivation, and interpersonal skills. However, these surveys focus only on the US industry.

Stevens and Norman (2016) surveyed the Information technology sector about graduate skills, and found that there was an identified need for more soft skills. However, whilst this sector includes Software Engineers, it involves other software professionals, and our specific focus is SE graduates, particularly those from our University, which has the longest running SE program in the country, with the first intake in 2000. The original syllabus was motivated by SWEBOK and later SE2004. The SE profession has since matured, and there is now a better understanding of what SE entails. We were interested in gaining insights on the local industry attitudes towards our curricula and identifying any gaps.

Methodology

Description of Survey

We created two online surveys to get feedback on the SE Program, one for the UoA SE Alumni and one for local SE professionals. The surveys, which had ethics approval, included Likert scale and open-ended questions. Respondents rated the importance of multiple SE related skills (listed in Table 2) and the ability of SE graduates in these skills. Similar to Lethbridge (2000) and Aishem et al. (2009, 2012) the skills were topic areas within SE (based on topics covered by the current UoA curriculum). In addition, we also included key graduate attributes inspired by graduate competencies from the Institute of Professional Engineers New Zealand. To rate the importance of SE related skills, we used an unbalanced (skewed towards the positive) rating scale since we expected mostly positive answers and

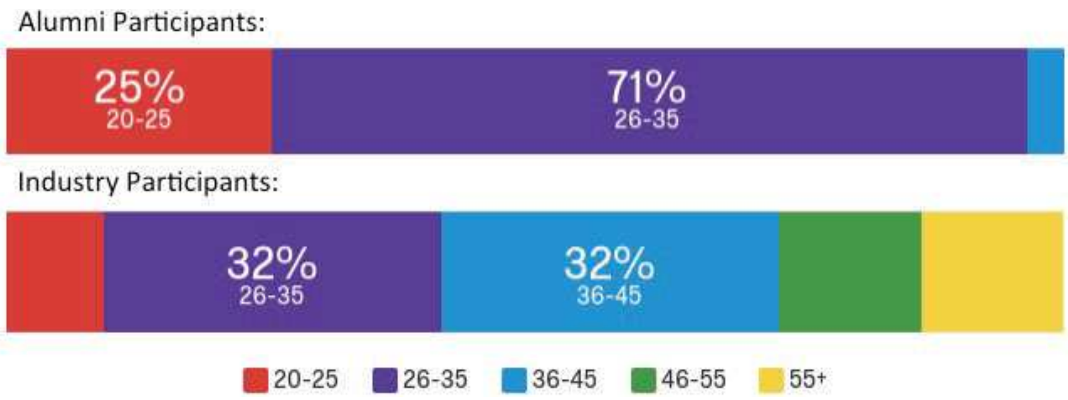

Figure 1: Age of survey participants

wanted to measure the degree of the responses (Parasuraman 2006). Respondents also provided opinions on various aspects of the SE degree. The full survey can be found online [3].

Survey Participants

The survey was sent to UoA SE alumni and professionals working at local software engineering companies. We got responses from 28 Alumni, 26 of whom stated they were currently working in the Software Industry. For the SE professionals, we obtained 22 responses, including 18 who said they are often involved in hiring decisions. We asked each participant several demographic questions including age, gender, years of experience, and education level.

Not surprisingly, our Alumni respondents tend to be relatively young, due to the short duration of the SE program; only one of the Alumni respondents was older than 35 years old. The SE Industry respondents are more varied with respect to age as shown in Figure 1. The Industry participants also had more experience working in the SE industry than the Alumni participants. The Alumni participants had 6.5 years of experience on average, compared to 14 years for the Industry participants. The education level varied across both sets of participants; however, the Alumni participants have a slightly higher education level on average. This is likely due to the SE degree being a joint Bachelor/Honours degree, provided a minimum grade point average is obtained. The highest level of education for each set is shown in Table 1. The gender of our participants is in line with the current ratios in industry, with 16% of our respondents identifying as female and the remainder identifying as male.

Table 1: Highest education level of participants

Education Level	Alumni	Industry
High school degree	0%	13%
Bachelor degree	32%	35%
Honours degree	42%	30%
Masters degree	21%	22%
Doctoral degree	4%	0%

[3] http://kblincoe.github.io/survey/AAEE2017_Alumni_Survey.pdf and http://kblincoe.github.io/survey/AAEE2017_Industry_Survey.pdf

Results

Skills in Software Engineering

In our survey, we asked respondents to rate, using a five-point Likert-type scale, the importance of 37 different skills or knowledge areas. Alumni respondents rated the importance based on the skills needed in their current role, and industry respondents rated the importance based on their hiring decisions for SE related positions. The soft skills dominate the top most important skills, with "Working in a team", "Communication Skills" and "Solving problems in a team" being the top three ranked skills. Table 2 shows the average rating for each skill across all respondents. There was not a significant difference between the two groups of respondents.

Table 2: Mean importance of skills across all respondents

Rank	Skill	Rating	Rank	Skill	Rating
1	Working in a team	4.49	19	Software dev. methodologies	3.45
2	Communication skills	4.49	20	Parallel & distributed computing	3.28
3	Solving problems in a team	4.44	21	Requirements engineering	3.26
4	Professionalism	4.34	22	Data structures & algorithms	3.12
5	Software quality	4.19	23	Human computer interaction	3.12
6	Solving problems independently	4.12	24	Computer Networks	3.02
7	Working independently	4.09	25	High performance computing	2.93
8	Ethics	4.07	26	Algorithms for optimisation	2.81
9	Industry experience[4]	4.06	27	Operating systems	2.72
10	Programming	4.02	28	Artificial intelligence	2.40
11	Software design	4.02	29	Machine learning	2.35
12	Software architecture	3.91	30	Formal specification & design	2.33
13	Software testing	3.84	31	Mathematical modelling	2.28
14	Agile and lean software dev.	3.77	32	Digital systems design	2.19
15	Object orientated software dev	3.58	33	Robotics & intelligent systems	2.02
16	Database systems	3.55	34	Embedded systems	2.00
17	Computer security	3.51	35	Microcomputers	1.98
18	Project management	3.49	36	Computer graphics	1.93

[4] Industry experience results based on Industry participants only, as it was not included in the Alumni survey

Table 3: Top five skill gaps identified by Hiring Manager respondents.

Skill or Knowledge Area	Importance	Ability	Difference
Software quality	4.56	2.53	-2.03
Software testing	4.19	2.73	-1.45
Software design	4.19	3.07	-1.12
Communication skills	4.44	3.33	-1.10
Solving problems in a team	4.50	3.47	-1.03

We also asked the hiring manager respondents to rate their satisfaction with the abilities of software engineers they currently employ or manage for the same set of skills. When looking at the differences between the ratings for the importance of a given skill and the ratings for the actual ability of software engineers for that skill, the largest gap identified by the hiring managers was Software Quality. Table 3 shows the mean ratings for importance and ability and the difference between these ratings for the top five largest gaps.

When comparing the SE and CS graduates, the majority of respondents (20 of 26 or 76.9% of Alumni and 11 of 15 or 73.3% of industry respondents) believe there is a difference between the graduates of the two degrees. In addition, most respondents believe that there are unique benefits for each degree and that the degrees complement each other.

Word clouds from Industry participant responses describing the benefits of each degree are shown in Figures 2 and 3. The word clouds were generated by Qualtrics with the degree names removed as stop words. As can be seen, a CS degree was perceived to have the benefit of providing exposure to the latest technology and tools and a deep understanding of technology. The SE degree was described as providing more real-world, practical knowledge with a solid engineering background. In regards to the degree duration, the shorter duration of the CS degree was cited as a financial benefit for students, while the extra year of study was cited as a benefit of the SE degree for the ability to gain more knowledge and experience before entering the workforce.

The majority of SE professionals involved in hiring decisions stated that individual strengths and weaknesses of a candidate would be more important in their hiring decision than the difference between these degrees.

Figure 2: Benefits of Software Engineering

Figure 3: Benefits of Computer Science

Discussion

In terms of importance, our participants rate soft skills very highly. Soft skills dominate the top ten ranked skills, similar to what Aasheim and colleagues (2009, 2012) found. Aasheim et al. (2009) found that US industry ranked interpersonal skills as the most important followed by personal skills and, after that, technical skills. Leibenberg et al. (2015) only asked industry to rate technical skills and found that design skills were the most important skills in the South African Software industry, followed by testing and maintenance. These skills also rank highly in our study. This shows that whilst there will always be local influences on the industry needs, there is commonality across the international community.

We also identified some skill gaps. In the early 2000s, the skill gaps identified by industry were in human computer interfaces, real-time system design, software metrics, software reliability, and requirement gathering (Leibenberg et al. 2000). These gaps had largely disappeared post 2010 (Leibenberg et al. 2015). In our study, the three skills with the greatest gap were software quality, software testing and software design. These have some overlap with the largest skills gap identified by industry in Leibenberg et al. (2015) and in Lethbridge (2000). When comparing the results of our study and those of Lethbridge's 2000 study, the size of the skill gap in both software testing and software design is less in our study. Lethbridge (2000) identified gaps of 1.9 for Testing and 1.7 for Design, compared to our data, which shows gaps of 1.45 and 1.12, respectively. Both studies used a five-point scale, but further investigation is needed to verify if there is a statistically significant difference. The more recent study's findings were similar to ours (Leibenberg et al. 2015). This suggests a potential improvement in the teaching of those subjects over time.

Two soft skills - communication skills and solving problems in a team - were in the top five skill gaps identified by industry. While previous studies found a need for more soft skills (e.g. Moreno et al. 2012, Aasheim et al. 2012), these previous studies had an explicit IT perspective and were not specific to SE. Thus, this is the first SE focused study to identify a soft skills gap. This is interesting; because Tockey (2015) argued that SE hiring managers are not making soft skills explicit in software engineering related jobs and instead focus on more learnable, technical skills. Tockey (2015) argues this is to the detriment of the software industry. Our results indicate that there is at least some awareness by hiring managers of the need to further emphasize and prioritize soft skills.

Limitations

Our survey respondents were self-selected, and their opinions may not generalize to all SE professionals. However, our sample size was comparable to many similar studies described in the related work (eg. Kitchenham et al. 2005, Surakka 2007, Stevens and Norman 2016). Importantly, we obtained responses from Alumni of the SE degree at UoA (of which there is a small pool) and from professionals working at nearly all of the local software engineering companies. Of course, it is likely that many of the Industry respondents do not have SE degrees, so they may not be as familiar with the SE degree as our alumni respondents. However, since the goal of the study was to understand the perceptions of the software engineering degree of those currently employed in the SE industry, the degree our industry respondents obtained is not important. All industry respondents work at software engineering companies and have, on average, more than 13 years of experience in the SE industry.

Conclusion

We conclude that soft skills (like working in a team and communication) are critical skills needed in SE. Thus, SE degrees must include these important components. There are areas where programs could improve, particularly around improving the software quality skills of graduates. Another important finding is that industry does perceive a difference between a SE and a CS graduate, and that both are needed in the software industry.

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Quantitative Research Design to Evaluate Learning Platforms and Learning Methods for Cyber-security Courses

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Teaching security courses is a challenging task in computer science program since it requires careful integration of theoretical concepts with their practical applications. In this paper, a quantitative approach is used to evaluate effective learning platforms and different learning styles for cyber-security courses. The outcomes of the study show that practice-based learning is the most effective learning method for cyber-security courses and student performance can further be enhanced significantly through social learning instead of solitary learning.

PURPOSE The main goal of this research is to understand the effects of learning styles and platforms for successful adaptation of different pedagogical practices. The following research questions are designed to achieve the expected outcomes.

- ✓ For cyber-security courses, does the performance of a student match with his/her self-specified learning performance?
- ✓ How learning platforms affect a student's performance in cyber-security courses? What factors play significant roles to successfully run a cyber-security course?
- ✓ Which type of learning mechanism is the most effective for cyber-security courses? Is learning in a group better than individual learning?

APPROACH Quantitative research is defined as a scientific method which follows a number of procedures such as generation of models, identifying theories and hypotheses, development of instrumentals and methods for measurement, experimental control and manipulation of variables, collection of empirical data, modelling and analysis of data and evaluation of results. This research follows experimental modes of inquiry which follows a standard form namely, participants, materials, procedures and measures.

RESULTS The results show that there is no single platform that includes all features to successfully run a cyber-security course. However, this problem can be solved by integrating those features with existing platforms. The study also suggests that learning performance can further be enhanced by choosing appropriate learning style.

CONCLUSIONS This paper investigates the impacts of learning platforms and learning strategies for cyber-security courses. Similar experiments from different aspects will be interesting to test their validity. The outcome can be used for further decision making e.g., the correlation of learning style difference could help to determine whether customized learning styles would be more effective for teaching cyber-security courses

KEYWORDS Quantitative research, Learning style, Cyber-security

Introduction

With the increased use of World Wide Web, malware and cyber-threats have also increased exponentially in the last few years. While cyber-attacks have been growing rapidly, it was predicted that there would be a global deficit of about two million cyber-security professionals in 2017 (Zantua, Dupuis, & Popovsky, 2015). This shortfall in critical cyber-security skills can mainly be overcome by promoting cyber-security programs in higher education. However, teaching cyber-security at undergraduate or postgraduate levels has been challenging for a number of reasons and has led to a shortage of qualified people with the right skills. This global phenomenon is due to lack of expertise and resources to develop and teach such programs, and keep up with continuously evolving discipline. The digital disruption and adoption of fast changing technologies by businesses and customers create a perfect environment for adversaries. The unknown vulnerabilities, zero-day exploits, high risk levels and possible consequences with lack of countermeasures leave the governments, businesses and industries off-guard. From world leading organizations to small businesses have fallen victims and became an embarrassing situation for nations.

The solution to cyber-security challenges begins from creating skilled workforce in this space, who will have the fundamental knowledge and skills to evaluate and address issues. Since any security solution is a balancing act, the fact evolving nature of threats require understanding and appreciation of the issues at all levels. This demands immediate action to roll out programs by educational institutions at various stages: undergraduate, postgraduate, professional development, up-skilling of workforce etc. Scholarship of Learning and Teaching needs to happen to steadily improve cyber-security education and cope with future challenges. Since learning platforms and individual learning style play a significant role in students' performance, this study uses a quantitative approach to evaluate them in real classroom environment. Quantitative research deals with systematic and scientific investigation of quantitative properties and phenomena, and their relationships. One of the key benefits of quantitative approach is that the procedure ensures reliability and validity of experiments. The main goal of this research is to understand the effects of learning styles and platforms for successful adaptation of different pedagogical practices. The following research questions are designed to achieve the expected outcomes.

- For cyber-security courses, does the performance of a student match with his/her self-specified learning performance?
- How learning platforms affect a student's performance in cyber-security courses? What factors play significant roles to successfully run a cyber-security course?
- Which type of learning mechanisms is the most effective for cyber-security courses? Is learning in a group better than individual learning?

Related Works

Extensive research have been conducted to investigate the applicability of both new and existing learning styles and platforms during last few decades. This is becasuse learning platforms and learning strategies have significant impacts on learning outcomes. A learning platform is an integrated set of interactive services that provides the participants access to common resources and communication tools as well as exchange information with each other. Similar to learning platforms, learning strategies also offer a number of ways to enhance learning capabilities. For example, problem based learning provides an efficient way to acquire basic competencies where students learn about a topic through the solving of problems (Gorghiu, 2015). In contrast, students are presented with the problem in inquiry based learning and asked to demonstrate self-analysis and critical thinking required to solve the problem (Gordon, 2015).

Sheen (2015) proposed an extensible technology framework for cyber-security education. The paper explores different types of teaching methods, technology, and means used to explain theoretical concepts. The framework uses a central engine to coordinate learning management with infrastructure in order to reduce administrative burden in cyber-security education.

Alshammari, Anane, and Hendley (2015) proposed an approach for learning style adaptivity and developed an e-learning system to facilitate personalized and adaptive learning. The authors also conducted experiments on sixty subjects and the results indicate that matching learning materials with learning style of the students significantly enhance learning gain and satisfaction.

Bell, Vasserman, and Sayre (2015) developed an assessment tool that can be used to measure student interest and self-efficacy in relation to cyber-security. This tool enables educators to detect changes in student outcomes and thus helps in systematically improve pedagogical strategies.

Cheung, Cohen, Lo, and Elia (2011) used Challenge Based Learning (CBL) methodology to cyber-security courses. In this approach, students are encouraged to collaborate with their peers, ask questions and develop a thorough understanding of the studied concepts and solve real world challenges. In addition to this, participating in cyber-security competitions, publishing research findings and making presentations are held regularly for guiding activities.

In this paper, our main emphasis is on different learning styles and platforms that can be used to enhance learning performance of students in cyber-security courses. Modern learning platforms like PebblePad, Blackboard and Facebook page are also evaluated in the experiments as they are most commonly used tools for interactive learning.

Quantitative Research Methodology

Quantitative research is defined as a scientific method, which generally follows a number of procedures such as generation of models, identifying theories and hypotheses, development of instrumentals and methods for measurement, experimental control and manipulation of variables, collection of empirical data, modelling and analysis of data and evaluation of results (Cresswell, 2003). The quantitative research methodology includes less rigorous experiments known as quasi-experiments, which are more suitable compared to true experimental designs as it does not have any time and logistical constraints. This research follows experimental modes of inquiry, which follows a standard form namely, participants, materials, procedures and measures. The following subsections describe these four forms of experimental methods used in this research.

Participants

For this experiment, 30 undergraduate students of the Network Security course and 21 postgraduate students of the Network Information Security course have been selected, who are studying Bachelor of Information Technology (BIT) and Masters of Information Technology (MIT) programs. This study follows a 2 × 2 × 2 factorial design: resources (learning platforms, learning styles), statement of values (implicit, explicit), and participants' identification (BIT, MIT). In addition, another dimension: individual versus group is also included in the experiments as a control and relevant for learning styles.

Variables

The main objective of this research is to evaluate the impacts of learning platforms and learning styles for cyber-security courses. A number of standard questions are designed for experiments to collect each student's individual preference. The collected data are tested and verified against real time responses conducted throughout the courses. The implicit statement of values condition is measured from the standardized format used in the experiment, whereas the explicit statement of values condition is obtained measuring the responses of the participants (BIT and MIT). Group experiments are also designed to analyze the treatment variables and the performance measures of the students obtained from the experiments are used to draw the final conclusion.

Instrumentation and Materials

The experiments are conducted for six consecutive weeks during lab hours and each week students are asked to answer or solve a number of questions. In first part, students are provided five technical questions and engaged in a repetitive question and answer session to find the correct solutions. The second part consists of five complex and challenging problems to be solved collaboratively. For the third part, a number of practice questions are provided and on the basis of knowledge acquired to solve those problems, the students are asked to solve five related questions. The answers are collected through three different platforms namely Blackboard, PebblePad and Facebook page. While submitting answers through PebblePad, students faced problems to upload their answers because of missing instructions. A mock experiment with dummy questions is held to overcome the problem. The following topics are used in undergraduate questionnaires: Unix Programming, Public Key Infrastructure, Hash and Digital Signatures, Security Tools, SQL Injection, and Same Origin Policy. On the other hand, postgraduate questionnaires include Advanced cryptographic schemes, Cipher modes, Secure Electronic Transaction (SET), Intrusion Detection System (IDS), Firewalls, and IP traceback. Some of these questions are descriptive (e.g., which features differentiate intrusion prevention system from IDS?) whereas some others are technical (e.g., for a given network scenario, what configurations should be changed to establish a telnet connection between two systems?). At the end of each week's workshop, students' answers are collected through learning platforms for evaluation. The outcomes are the average of the students' six weeks performance.

Experimental Procedures

The experimental procedure includes four steps: i) collection of demographic data, ii) learning platforms, instrument and materials, iii) learning styles and iv) learning tasks. In learning tasks, students answered a number of questions related to weekly lectures. Three learning platforms are used alternately to obtain the answers and the measurement is done on collected data to evaluate students' self-reported learning styles. As mentioned above, a mock session has also been conducted to overcome the PebblePad problem and the new results are recorded for analysis. Another experiment is done by randomly assigning students into groups (ten undergraduate and seven postgraduate groups) where each group consists of exactly two members. We have used the 2 × 2 × 2 factorial design experiment that uses two treatment variables to examine the performance as well as effects of the treatment variables on final outcomes. In this task, students are asked to develop a simple host based Intrusion Detection System. All students received the same background knowledge required to solve the task. The experiment has been conducted from two dimensions: one is problem/ practice based solution (*A*) that seems to be relevant to learning styles whereas individual/ group (*B*) dimension serves as a control. The first group only receives the treatment as shown below.

Group A: *R* ---------- *O* ------------- *X* ----------------- *O*

Group B: *R* ---------- *O* ----------------------------------- *O*

Here, ***X*** denotes treatment, manipulation, induction, ***O*** denotes measurement, observation, and ***R*** is random assignment.

Threats to Validity

Threats of validity are classified into two categories: i) internal validity threats and ii) external validity threats. The following subsections describe each of these threats.

Internal Validity Threat Control

History- In this experiment, both groups have experienced the same current events. So no other current event affected the change in the dependent variable. *Maturation*- No changes occur in the dependent variable due to normal experimental processes because both groups experience the same experimental processes. *Selection*- As all the subjects are selected and all of them have received treatment or control condition, there is no impact on the dependent variable. *Experimental Mortality*- It means that whether some participants drop out and does it affect in the results or not. In the experiments, the same participants involved in the entire study in both experimental and control groups, so there appears to be no bias. *Testing*- Both groups get a pre-test in the experiment but a pre-test may have the experimental group more sensitive to the treatment. *Instrumentation*- The measurement method, materials and instruments have not been changed during the research.

External Validity Threats Control

Unique program features- A motivated set of facilitators for small group discussions may exist. *Effects of Selection*- probably applicable to other computer science courses. *Effects of Setting*- computer science students have their own culture, so it is doubtful if this would be applicable to other types of students such as medical students. *Reactive effects of experimental arrangements*- it would be better to imitate the results in other related programs.

Results and Analysis

The first experiment has been designed to test whether the performance of an individual student matched with his/her self-specified learning performance. The outcomes indicate that problem-based learning is more preferable compared to inquiry-based and practice based learning styles for cyber-security courses. *78.43%* students have found right answers through problem-based learning, whereas the amount for practice-based and inquiry-based learning is *62.74%* and *54.90%* respectively. This outcome is consistent with their self-reported learning styles as shown in Figure 1. The percentile representation of experimental outcomes shows that 40% students learn better through problem-based learning whereas the number is 32% and 28% for practice-based and inquiry-based learning respectively. These figures are very close to their self-specified learning styles where 46% students chose problem-based learning, 30% of them preferred practice-based learning, and the rest 24% students specified inquiry-based learning.

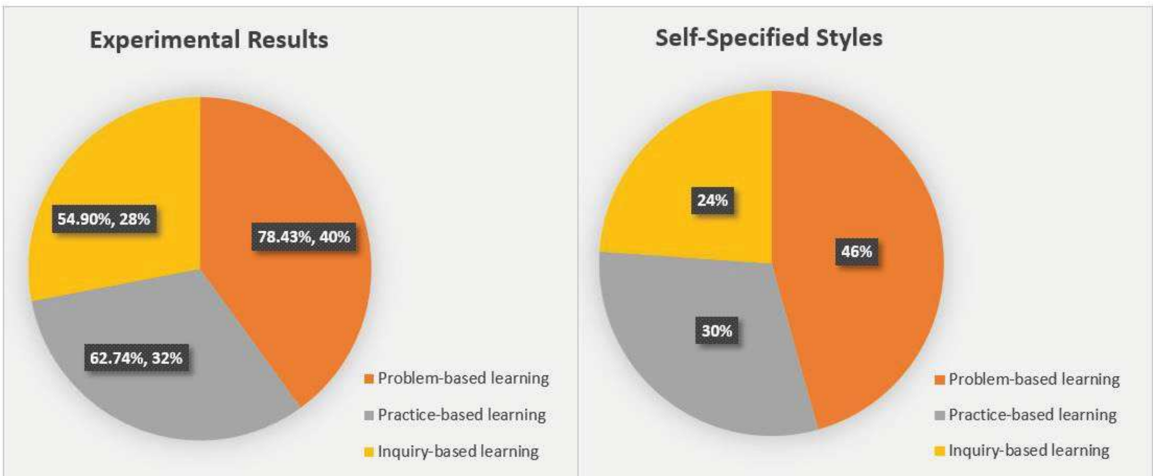

Figure 1: Learning performance outcomes for different learning styles

The second experiment is conducted to examine the impacts of different learning platforms. Students' responses are observed and accuracy is measured in terms of successful collaboration and effective use of provided resources. The outcomes show that *67.78%* accuracy is achieved while using PebblePad, whereas the level of accuracy obtained for Blackboard and Facebook Page is *53.30%* and *49.23%* respectively. However, in self-specified instrument, *38%* students chose to use Blackboard while *33%* and *29%* of them specified PebblePad and Facebook Page as their preferred learning platforms as shown in Figure 2. Thus, experimental results do not support self-specified learning platforms. We noticed that PebblePad supports some unique features compared to other platforms such as individual feedback, group feedback, sharing workbook with any group member. PebblePad is a good learning platform for collaboration among group members and course instructor. Although Facebook Page is more user friendly, it doesn't provide most of the basic features such as setting submission deadline, student grading and integration of third party tools. On the other hand, Blackboard supports many third-party tools such as SafeAssign, TurnItIn, Tweak and WebAssign. However, in addition to other limitations, Blackboard is not user friendly like PebblePad and Facebook Page. From the experiments, it is understandable that there is no unique platform, which provides all necessary features to run a cyber-security course. In terms of students' satisfaction and learning performance, PebblePad outperforms other two platforms in our experiments.

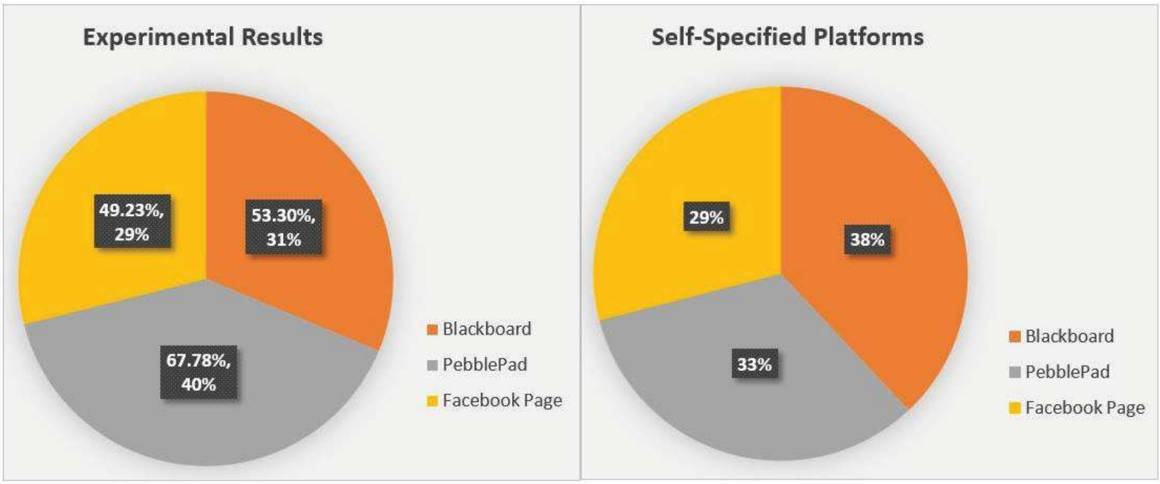

Figure 2: Impacts of different learning platforms on learning outcomes

To address third research question, students are divided into multiple groups with exactly two members: ten undergraduate groups and seven postgraduate groups. In this task, undergraduate and postgraduate students are asked to develop a simple IDS and an advanced IDS respectively using shell script in groups and individually. The IDS has two parts: i) verification file generation and ii) intrusion detection. Practice-based learning method has been implemented as a learning strategy for the first part whereas problem-based approach is followed for the second part. Students are taught basic shell script programming and essential features required to design the IDS. From obtained results, it was found that *88.23%* students in groups could solve the part 1 using practice-based method, whereas it is *64.70%* for individual. On the other hand, part 2 is solved by *76.47%* students working in groups, whereas it is *47.05%* for individual learning. We also calculated the *chi-square p* value with one degree of freedom. The *p value* is *0.478*, which indicates that there is no statistically significant difference between the observed value and the expected value. Thus, the experimental outcomes indicate that learning in groups is more suitable compared to individual learning for cyber-security courses. Similarly, practice-based learning is more effective than problem-based learning according to obtained results.

Conclusion

This paper investigates the impacts of learning platforms (Blackboard, PebblePad and Facebook Page) and learning strategies (inquiry-based, problem-based and practice-based) for cyber-security courses. Similar experiments from different aspects (e.g., Yammer platform and project based learning) will be interesting to test their validity. The results show that there is no single platform that includes all features to successfully run a cyber-security course. However, this problem can be solved by integrating those features, wherever possible, with existing platforms. The study also suggests that learning performance can be enhanced by choosing appropriate learning style. The outcome can be used for further decision making such as the correlation of learning style difference could help to determine whether customized learning styles would be more effective for teaching cyber-security courses. This paper will provide a good background for researchers interested to perform further research in cyber-security education. Our future work aims to evaluate other learning platforms and learning styles to examine their applicability for cyber-security courses.

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Curriculum Transformation with Students as Partners

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Introduction

8732142. That was my student ID as an undergraduate (now one of the authors).

It was a number, not a name. It distinguished students from professors and all other teaching staff and, in a symbolic way, reminded us all of our firm place as students, as learners. There was a big power differential between students and teachers in the 1980s. What we learned was prescribed, transmitted and tested in implicit ways (no rubrics or marking criteria in those days) and rarely were our *skills* tested – just what we knew and could *recall* at a given time.

Sometimes people say that teaching is an *act*. Indeed, *sage on the stage* suggests this precisely. But being a student is also an act. Students also assume roles and personas.

If we want curriculum transformation, we seek to put a stop to acting – to engage students and staff in *authentic learning*.

MIDAS is our curriculum transformation project in the Faculty of Engineering and Information Technology (FEIT) at UTS – More Innovative Design-Able Students. In MIDAS, we want students and teachers to be their authentic selves in a true teaching and learning partnership. MIDAS seeks mutual respect in people, not the fulfilment of roles.

MIDAS doesn't see students as numbers, but as partners, as people who can learn, contribute, inspire, teach and create … and it sees teachers as people who also learn, contribute, inspire, teach and create.

MIDAS – More Innovative Design-Able Students

MIDAS is a 5-year cultural transformation project that is reinventing curricula, learning and teaching practices, through student and stakeholder engagement, to prepare graduates for the new world of work in the 21st century, requiring a focus on innovative design practices.

Many reviews of engineering education in the last 15-20 years have urged transformation of engineering education (D. Beanland & R. Hadgraft, 2014; Carnegie Foundation for the Advancement of Teaching, 2009; Institute for the Future, 2015; R. King, 2008; National Academy of Engineering, 2004, 2005; S. D. Sheppard et al., 2008; N. Spinks et al., 2006).

These international reviews recommended several issues to be addressed such as: complex challenges, interdisciplinarity, creativity and invention, leadership, sustainability, global ethics, and lifelong learning (R. G. Hadgraft, 2017). Curriculum changes suggested included: a professional spine, teaching for connection between topics, approximate engineering practice, use case studies, situate problems in the world. The Henley Report (N. Spinks et al., 2006) recommended three different kinds of engineers: the technical specialist, the integrator and the change agent.

Through the MIDAS project, staff and students are engaged as partners in activities and conversations to build capacity for a better learning experience, one that prepares students and staff for these challenges in the future workforce.

The Learning Design Team in FEIT is building a sense of urgency to improve the student experience. How might staff create shared values – to discover, engage, empower, deliver, sustain? The team aims for heightened awareness and traction – traction for transformation of mindset, beliefs, values and behaviours.

In every conversation we have, in every action we take and in all our endeavours, we aim to create a place where students are at the centre of these transformative conversations. Together we aim to graduate students as successful engineers and information technologists of the future, who are more innovative in their approaches, who use design thinking at the core of their practices.

In summary, the key principles underpinning MIDAS are:

1. A student-partnered curriculum, creating a vibrant and exciting student experience that matches the Engineering and IT professions, with a focus on innovation and entrepreneurship.
2. Student-centred learning with e-portfolios, learning contracts, project-based studios and online learning as key ingredients of this new learning environment.
3. A new, responsive curriculum structure that reflects the changing nature of engineering professions, driven by AI, automation, data analytics, climate change, etc. Cross-disciplinary learning needs to be a common practice.
4. Connected teaching and research, so that our research centres run inspirational studios and capstone projects at senior levels of our programs to draw students into their research programs.
5. A collaborative environment where students, academics and external stakeholders work together for the benefit of all parties, the faculty and university as a whole.

The University Context

How did MIDAS come about?

In 2014, UTS embarked on a university-wide initiative to reform its teaching practices (UTS, 2017). Each subject in the university must embrace key teaching and learning principles that are neatly summarised as ABC:

A. Active and Authentic Learning and Assessment – real world tasks and projects
B. Blended/Flipped learning – put lecture materials online, where possible, and have students come ready to class to engage in problem solving using:
C. Collaborative learning

Subject outlines have been revised across the university through 2014-17, resulting in many difficult conversations and reconceptualisations in our Faculty of how technical topics might be taught. What has become clear is that many academics have never really thought much about *why* a subject, or a topic within a subject, needs to be learned or, indeed, what its end purpose might be. Getting them to think about a real design task that would embody the theoretical ideas has been quite difficult in some cases. Getting them to take action has required courage. Nevertheless, once that has been achieved, the academic has often seen their subject from a whole new direction and has become energised to engage the students in real problem solving. Students benefit from the real-world projects because they place the difficult theoretical ideas into context.

Why Studios?

Engineering and Information Technologists use design processes to solve complex problems and to develop new product opportunities (B. Koen, 2003). The Faculty's *Graduate Attributes,* adapted from I. Cameron and R. Hadgraft (2010), embody the capabilities necessary for professional practice. A graduate is expected to be able to:

A. Investigate the client's *needs*,
B. Use a systematic *design* process,

C. Apply disciplinary *technical* skills,
D. *Communicate* and *coordinate* tasks with co-workers and stakeholders,
E. *Self-manage* tasks, projects and career development,
F. All within a *global context*.

Although there has been a history of project-based learning in the Faculty for many years, we are now planning to take this to the next level, shifting the emphasis from Projects to Student Learning. Studios embody that shift (R. Hadgraft et al., 2016), with each semester having a studio component of 25-50%, surrounded by more traditional teaching of skills.

Studios provide students with open-ended project opportunities to develop the full range of professional capabilities. Each student defines a set of intended outcomes in a learning contract and then works to satisfy them, which they then document in a personal *e-portfolio*. Studios require graduate attribute E in action – self-management and self-learning.

A challenging task requires first an understanding of its *context*, the system in which it is embedded, the client *needs* must be identified, and formally recorded as the *requirements* to be delivered (point A above). These authentic project tasks will usually be developed with industry partners.

Students use the *design* process (point B), empathising with the stakeholders to understand the problem as deeply as possible. The initial focus is on problem definition. Is the problem clear? Are the requirements clear and deliverable? (T. Brown, 2008; IDEO, 2017; Stanford University d.School, 2017)

In the process of developing a set of potential solutions and in evaluating them against the requirements, various kinds of technical (abstraction and modelling) skills will be required (point C).

Engineering and IT rarely happens as individual activity – *teams* are required almost always. *Communication* and *coordination* are key skills (point D), likely the most important skills across a career (J. Trevelyan, 2014). EIT professionals spend around 60% of their time communicating both within the team and across team boundaries.

Self-management (point E) is the key ingredient. Engineers and IT professionals must be able to manage their work, learning and time to become reliable and productive team members. The studios require students to maintain a reflective journal that will help them to identify strengths and weaknesses, to shape their learning across technical and non-technical capabilities.

Finally, studios will help students to see the global nature of engineering and IT practice (point F), both in the context of problems and design opportunities but also in the nature of the teams in which they will work, blending cultural and disciplinary perspectives.

The studio is the vehicle for each individual's learning, as part of their overall career development at the university. Their personal e-portfolio will be a record of their achievement of the graduate capabilities and of their readiness to step into the world of work, or even define their own work world. It will contain many examples that might be discussed at a job interview, demonstrating the graduate is work-ready. Importantly, development of an e-portfolio requires self-reflection, a key professional capability.

Student Involvement

The key part of the MIDAS project is involving students as partners in their own education. Things get done *to* students in the current university environment. We want to change that.

The core MIDAS team is working with the University Innovation Fellows (UIFs), four students from third, fourth and fifth years across different engineering disciplines. They are the first students to be selected as part of a Stanford University program empowering students to become agents of entrepreneurial change at their universities using *design thinking* as a tool (d.School, 2017). Each of these students undertook online training in Feb 2017, followed by a week of immersion in design thinking at Stanford in March.

The UIFs have so far encouraged student feedback from different cohorts about Faculty programs. They work alongside academic and professional staff to bring about changes students want, such as forums and workshops. The UIFs have also accepted the task of drafting a proposal to repurpose a designated student learning space in our building, finding out how students want to use it and what needs to be added and changed. This is a very exciting and growing enterprise.

Another initiative is *Learning about Learning*, which aims to meet the learning needs of students in the Faculty, working with the Student Promotional Representatives of UTS (SPROUTS), students who are pivotal in gaining other students' engagement in conversations.

The UIFs, the SPROUTS and individual students from various study programs and professional backgrounds are also coming together as partners with teaching and learning staff to interpret student feedback surveys. They provide insights into improving specific learning areas and the wider student experience.

The MIDAS team has invited the UIFs and friends of UIFs to participate in conversations pertaining to Curriculum Renewal Projects including a new Mechanical and Mechatronics Program, a new Civil Engineering program and related sub-majors, a new Master of Engineering (Robotics), Renewed Core subjects, Innovation studios, and a Student Communication package.

Our Faculty has for two years now, insisted on student participation at retreats, workshops and forums. This year, 12 students attended the Faculty's Teaching and Learning Advance in September working alongside about 80 academic and professional staff in articulating stories of success and achievement. All have committed to continuing the work in learning partnerships with academics.

In the next section, students tell their side of this partnership in more detail.

Student Run Workshops using Design Thinking

To uncover the hidden pains and unfulfilled desires of students within our current education system an adaptation of the *Design Thinking* Process (Empathise, Define, Ideate, Prototype, Test) has been used in student-led forums and workshops. These forums are developed and run by student leaders in an effort to engage their peers and allow them to pinpoint key elements of the current university experience that need improvement. By allowing students to manage these workshops, a friendly and casual environment is established allowing honest thoughts and ideas to be uncovered and discussed – a crucial element to the success of the workshops thus far. A typical one hour workshop takes the following form:

1. *Empathise* – Participating students are asked to pair up with someone else in the room and converse over a given topic. For example: "Your First Year Experience at University" or "How You Travelled to University Today". The topic of this first activity is tailored to the group or focus of the forum. During their conversation, students are encouraged to ask "5 Whys" and follow up questions to their partner's statements in order to coax out the underlying reasoning behind their thoughts. Anything that the students find to be interesting, painful or unexpected is written down on post-it notes and dumped on butchers' paper.
2. *Define* – With a collection of post-it notes from the interviews, students then form larger groups and discuss what they uncovered. As a team, they must now choose one or a related combination of "pain-points" or interests from the collection which they must use to create a "Problem Definition". This problem definition must take the form of "How might we…". For example, "How might we help students form stronger friendships in their first year of university?" or "How might we help students feel safe on their way home from

campus?”. Stating the problem definition in this way allows joint ownership of the set task and opens the problem up to have a large number of solutions.

3. *Ideate* - In the same groups, students are asked to use the “Yes and…” mentality to rapid-fire idea generation surrounding their chosen problem definition. In this portion of the workshop anything goes and no idea is dismissed or discussed at length. Students are all encouraged to stand (not sit) and to contribute to a collection of post-it note ideas.
4. *Prototype* – At the conclusion of the idea generation phase the groups must now sort through all of their post-it notes and either as a standalone idea or as a combination, propose an intervention to their chosen problem definition. This intervention must then be turned into a physical/visual prototype by any means. Examples include storyboarding, role play and physical models made from craft materials.
5. *Test* – The groups must now show their prototypes to another group and have the other group experience the solution that has been created. With valuable feedback from rapid real-world testing, design iterations can be performed on any of the design stages until a satisfactory proposal has been developed.

The data gathered from these workshops has been invaluable in uncovering some true desires of the students. It also allows students to take ownership of problems they are facing and gives them the power to generate solutions within the space of the one hour session, resulting in a sense of pride, satisfaction and productivity.

This design process can be viewed on a much larger scale and forms a core process within the MIDAS project. By working with students as partners, a very deep level of empathy is able to be achieved as the students themselves are creating solutions to problems they are facing. In essence, it can turn the university experience into an open resource platform where students are provided with resources they need to conduct their studies and projects. Students are able to develop a greater understanding of their own thoughts and allows for reflection of situations in which they are faced.

Outcomes from Student Run Workshops

Student run workshops have uncovered numerous problems which students consider of high importance at UTS:

1. The need for **increased study spaces** on campus for both quiet study and for (noisier) group activities
   - One group proposed a coloured signalling system in the library to identify vacant study spaces for waiting students.
2. Desire for a **greater university-social balance**
   - Some students have proposed “chill out zones” to allow students to take a break from study and to socialize with friends.
   - “Nap pods” have been requested by groups of students who travel long distances to get to university and believe a nap would help them maintain focus later in the day.
3. **Greater support for student entrepreneurs**
   - Some students have discussed a desire to start their own businesses or look into the “start-up culture” but are unsure how they could pursue these avenues without affecting their studies.
4. **Project based learning**
   - Many students have expressed high interest in increased project based learning both in the forms of practical classes/ assessments and in internship/work experience opportunities.

Overall one of the biggest insights into the current student mindset is that students are eager to learn and have a large desire to be challenged and to do well in their studies but they feel as though they are sometimes lacking the resources and necessary support. Resources such as face to face time with lecturers, hands on projects, clear instructions, flexible assessments and increased space to undertake study have all been repeatedly named.

With this comes some surprises, however, as many students are also unaware of some of the opportunities and resources already available to them. It is possible that one of the key outcomes from these workshops is that resources need to be more visible and actively promoted to students to give them the greatest opportunity to make use of what is available.

The second biggest insight from these workshops is the interest that students take once they are exposed to the design process. Once they have gone through a few iterations of the process many have been very eager to participate in following sessions and are open about their desire to continue shaping the university to suit their needs. This again comes back to the core principle of MIDAS – having students as partners.

A university is much more than a business selling education, although some of the same principles apply. When developing any product or selling any service, the business will flourish if its customers are satisfied and they feel as though they are the company's number one priority. If students can see that they are being put first and that the university is there to benefit them and grow with their needs, the success of those students and the reputation of the institution as a whole will follow.

Further Exploration of Student Issues

We also have the good fortune to have an external facilitator working with us on the change management processes behind MIDAS. Greg Jenkins tells how he has been running World Café (World Café, 2017) conversations for a few weeks now. The aim of these conversations has been to get at the heart of the issues that trouble both students and staff: how can we create a learning and teaching environment that is more satisfying for us all?

Here's Greg's brief explanation of the process:

The genius in the World Café approach is that it makes it safe to have conversations that matter in groups of 3-5 around small tables. However, doing something once never gets to the real depth of an issue. It's no surprise that nothing much changes without a regular chance to dig deeper into issues – to find the elephant in the room. In my experience, it is also vital that a member of the management team be present at every conversation, so that key issues can be progressed.

To what extent does a corporate process like this translate into working with university students? Culture is complex anywhere. In a large university, there is a whole new dimension to understanding the really deep issues, the elephant in the room.

There seem to be a huge number of surface issues about teaching and learning and student engagement and leadership that look impossible to understand let alone resolve and there are not a lot of deep conversations between students and teachers, between teachers themselves, and between university leaders and teachers and students. Everyone seems too busy to have those extended conversations. There is also plenty of feedback from students to teachers and to the university through formalised student feedback surveys. With so much communication happening, why have another methodology?

There is a problem with aggregated feedback in that it is all either *from* individuals or *to* individuals: one to many or many to one. It's hard to get heard no matter how good the feedback or how powerful the communication. There is just so much to take in that it's hard to get attention.

That's why we are trying the World Café conversations with students. We have now conducted more than 10 of these small table conversations Each weekly session takes an hour.

What's going well: The attending students are fully engaged and thoughtfully contributing to the conversation. Each innovation café goes deeper from the previous conversation. These are high quality conversations that have the opportunity to put issues in a different light. I'm confident that we are getting closer to the 'elephant in the room'.

One issue that consistently emerges is CARE – academics caring about students and about creating a good learning environment, students caring about their learning, and everyone caring about sharing honest feedback with each other. This theme of caring aligns well with the intended outcomes of MIDAS – to create a learning environment where students can own their own learning and develop themselves in a safe environment.

Summer Studios

Summer studios are one opportunity to simultaneously address student dissatisfaction at having few subject offerings over a summer term and also to launch the MIDAS project. To date, over 360 students have expressed an interest in participating in a studio experience.

What are summer studios?

Summer studios are designed to be high energy, high collaboration, project-based subjects where students can engage in real-world challenges. They are facilitated by a mixture of academic experts, industry and community partners. Using a design thinking framework, students regularly engage in pitching and critiquing work among peers.

Academics, students and industry partners have proposed a range of projects broadly clustered into the following areas:

- Meeting future human needs in cities and developing countries
- Data science and artificial intelligence
- Design and build amazing devices

Students as partners is seen in this initiative in two key ways. First, the design of the studio is pedagogically student-centred and fosters relevance, which has been another key area of concern for students.

Second, four senior undergraduate engineering students have taken leadership of individual studios and will be lead facilitators – humanitarian engineering, smart cities, a Vivid lighting installation and space engineering.

Conclusions

MIDAS is about the future state of engineering education at UTS. We believe education strategies and practices need to continuously adapt to a rapidly changing world. Our new curricula will be based on transformative, collaborative and continuous renewal.

Our studio-based curricula embody the key ideas from the international reviews: a professional spine of projects modelled on engineering practice, using real scenarios from industry and community partners.

In MIDAS, students and academics will get to be their true and authentic selves. Our students and academics will engage in genuine, mutual and authentic partnerships. MIDAS respects that students and academics are on a journey together, both seeking meaning and both teaching and both learning. This is a process of continuous and transformative change for everyone.

MIDAS aims to build the support system required to enable the drivers of our future education. It has a positive vibe that harnesses and attracts staff and students and the wider community. Together, we rely on the design thinking process to help us achieve remarkable feats.

Just as NASA placed a man on the moon and SONY put a music player in our pockets, so MIDAS aims for *transformation*. We focus on the a-ha moments. We've all had them, mixed with feelings of fascination, inspiration, discovery, challenge and success. We remember them. There's a connection. Something feels unlocked. It sticks with us. What we're looking at suddenly seems very different. We share our stories about them. Creating sticky stories and storytelling is one way to help unite this culture of continuous change in the Faculty and we have found that student stories are often the most urgent and compelling.

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Improving Presentation Skills of First-Year Engineering Students using Active Video Watching

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CONTEXT

Transferable skills are highly sought by employers and deemed crucial for employability. Research shows that transferable skills contribute as much as 85% to students' success (Wats & Wats, 2009). Teaching transferable skills to tertiary students in technical and business disciplines is time-consuming and difficult to document.

PURPOSE

We conducted a study to determine whether presentation skills can be taught online, using AVW-Space, a controlled video-based learning environment.

APPROACH

A large scale experimental study was conducted with engineering students. In the first phase, the students were instructed to watch and comment on eight videos individually, and after that (in phase 2) to rate comments written by others. Two surveys were administered, before and after interaction with AVW-Space. We also collected data about students' interactions with AVW-Space, as well as the marks students received on their presentations.

RESULTS

The study provided insights into student engagement with videos and the impact on developing presentation skills. Out of 904 enrolled students, 463 completed Survey 1 (pre-training), and 324 students watched videos in AVW-Space. We divided the participants who completed Survey 1 (pre-training) into three categories: Inactive (160 students who did not watch videos), Passive (153 students who watched videos but made no comments), and Constructive (150 students who watched videos and made comments). Constructive students wrote a total of 1,302 comments. The analysis of the comments indicated learning, with students noticing important elements of tutorials, as well as reflecting on their previous experience in giving presentations. We compared the presentation marks of the whole 2017 class to those of the 2016 class, when AVW-Space was not available. There was a significant increase ($p < .0001$) in presentation marks for the 2017 class in comparison to the 2016 class, with the effect size (Cohen's d) of 0.44. The only difference between the two courses was the use of AVW-Space. There was also a significant difference ($p < .001$) in presentation marks in 2017 between students who did not watch videos and those who did.

CONCLUSIONS

The results demonstrated that active engagement with videos promoted learning, leading to improved presentation skills. This gives strong support for using AVW-Space to augment transferable skills training for engineering students. In our future work, we will enhance the environment to provide adaptive feedback and support during active video watching.

KEYWORDS

Presentation skills training, video-based learning, active video watching

Introduction

Transferable skills (such as communicating, negotiating, collaborating, critical thinking, reasoning about societal/ethical responsibilities and intercultural awareness) are widely seen as crucial for employability in the knowledge economy (World Economic Forum, 2016; National Research Council, 2012; Spronken-Smith et al., 2013). Research shows that transferable skills contribute as much as 85% to students' success (Wats & Wats, 2009). However, it is challenging to teach transferable skills explicitly to tertiary students in technical and business disciplines (Anthony and Garner, 2016), as they are time-consuming and difficult to document. Students need to practice under various conditions, receive feedback, reflect on it and do more practice. Teachers typically do not have enough resources to provide such support to each individual student.

Videos can be a powerful method for transferable skills training (Cecez-Kecmanovic and Webb, 2000; Conkey et al., 2013; Cronin and Cronin, 1992), where learning requires contextualisation in one's personal experience and an ability to see different perspectives. Simply providing videos is not enough though, as watching videos is inherently a passive form of learning (Chi and Wylie, 2014), often resulting in a low level of engagement. In order to learn effectively, students need to engage with the video content and self-regulate their learning. One of the proven strategies to increase engagement is to integrate interactive activities such as quizzes into videos (Kovacs, 2016). Although this strategy increases engagement, it requires changing existing videos, resulting in substantial effort from the teacher.

We conducted a large-scale study to determine the effectiveness of teaching presentation skills using AVW-Space (Mitrovic et al., 2016), a controlled video-based learning environment. The previous studies (Mitrovic et al., 2017) showed that only students who were engaged during video watching by commenting on videos and by rating comments written by others improved their understanding of presentation skills. In this study, we focused on first-year engineering students: the study was conducted in ENGR101, a mandatory course at the University of Canterbury for all Engineering students. The course involves a group project, in which students work on an Engineers Without Borders design challenge (http://www.ewbchallenge.org/). At the end of the project, students are required to present their results. Due to the lack of sufficient lecture time and resources, the ENGR101 students do not receive any training on presentation skills. In 2017, we provided online training on presentation skills using AVW-Space.

In the following Section, we present the instance of AVW-Space used in the study, followed by the description of the experimental design. The research questions we focused on were whether the provided training for presentation skills was effective overall, and also for what type of students the training was beneficial. We then present the results of the analyses performed on the data collected during the study, and avenues for future work.

Teaching Presentation Skills in AVW-Space

AVW-Space is a Web-based environment which supports engagement during video watching via interactive notetaking, tapping into students' familiarity with commenting on videos in social networking sites. AVW-Space allows the teacher to select a set of publicly-available YouTube videos for students to watch. The environment supports engagement during video watching by providing micro-scaffolds to facilitate the commenting on videos and the reviewing of comments made by others.

The first phase consists of students watching and commenting on the videos individually. The instance of AVW-Space used in the study contained eight videos, which have previously been used in two studies (Mitrovic et al., 2017). Four videos were tutorials on how to give presentations, while the remaining four videos were example presentations (two TED talks and two 3-minute PhD pitch presentations). The student can stop a video at any time, enter a comment and specify an aspect, which indicates the intention of the comment (Figure 1). For the tutorials, aspects aimed at stimulating reflection included: "*I didn't realise I wasn't doing it*", "*I am rather good at this*", and "*I did/saw this in the past*". There was one additional aspect, "*I like this point"*, to encourage the learner to externalize relevant learning points. For the example videos, the aspects corresponded to presentation skills covered in the tutorials, which included "*Delivery*", "*Speech*", "*Structure*", and "*Visual aids*".

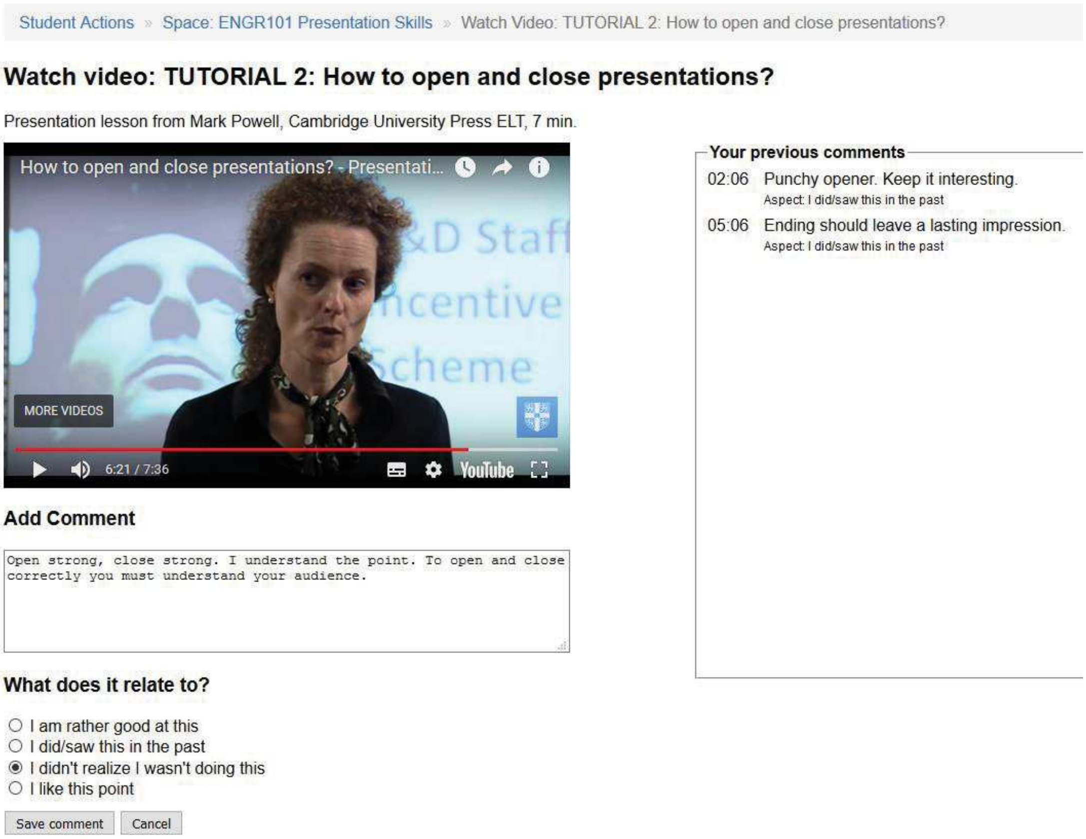

Figure 1: The commenting interface of AVW-Space

In the second phase, the teacher selects the comments that will be open to the whole class, so that students can review and rate each other's' anonymised comments (Figure 2). The student can click on the time a particular comment was made to watch the part of the video to which the comment refers. In such a way, the student can compare his/her own comments to those of others, and further reflect on their experience. The AVW-Space instantiation for presentation skills included five categories for rating comments: "*This is useful for me*", "*I hadn't thought of this*", "*I didn't notice this*", "*I don't agree with this*", and "*I like this point.*"

Experiment Design

The study was conducted with volunteers from ENGR101, and was approved by the Human Ethics Committee of the University of Canterbury. After providing informed consent, the participants completed Survey 1, which included questions related to demographic information, background experiences, motivation and attitudes using the Motivated Strategies for Learning Questionnaire (MLSQ) (Pintrich and de Groot, 1990). The students were instructed to watch the tutorial videos first, and then to critique the example videos, focusing on structure, delivery and speech, and visual aids. In the second phase of the study, students were asked to rate comments written by others.

At the end of the study we administered Survey 2, which included the NASA-TLX questionnaire (Hart, 2006) measuring the students' cognitive load, and the TAM questionnaire, measuring the perceived usefulness of AVW-Space (Davis, 1989). In addition to survey responses, we collected data about students' interactions with AVW-Space, as well as the marks students received on their presentations.

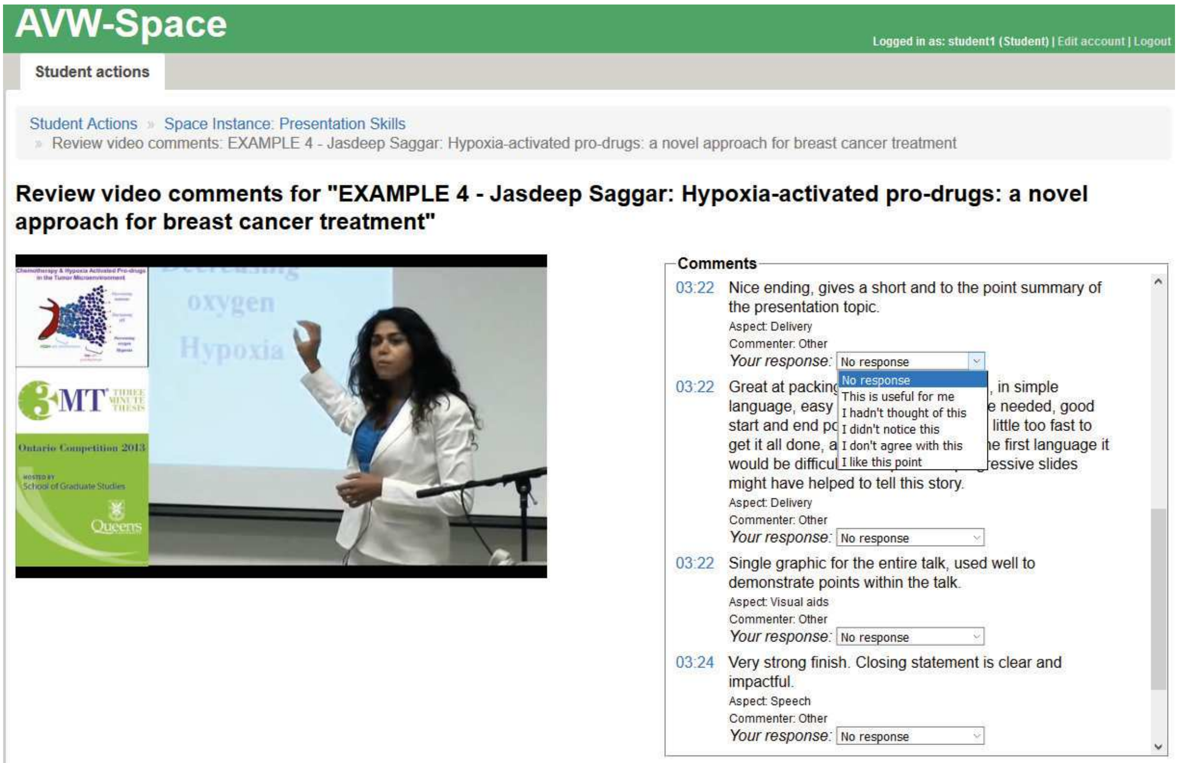

Figure 2: The rating interface of AVW-Space

Results

Out of 904 enrolled students, 463 completed Survey 1. Of those, 367 students logged into AVW-Space, but only 324 participants watched at least one video. Some students watched the videos passively, and made no comments. There were 164 participants who commented on videos, and wrote a total of 1,302 comments (mean = 7.94, sd = 9.51, range [1,75]). There were 334 students who completed Survey 2, but some of them either did not complete Survey 1 or did not watch any videos.

The first step of data analysis consisted of data cleansing. We removed incomplete submissions to Survey 1, and performed a post-hoc split of participants into three categories: the *Inactive participants* are those who have not watched any videos (160 participants), *Passive participants* who watched videos but made no comments (153 participants), and *Constructive participants*, who watched videos and made comments (150 participants). In the following subsections we discuss the findings using the data from those 463 participants.

Findings from the profile survey

Table 1 presents demographic data, as well as the summary of the MLSQ responses. The majority of participants were male (71.9%), which is common for engineering courses. There was no difference in ages of the three categories, with most of the participants being younger than 30. The majority (83.15%) were native English speakers (the *Native* row in Table 1).

Survey 1 had questions using the Likert scale from 1 (lowest) to 5 (highest) related to how much formal training the participants had on presentation skills, their experience in giving presentations, how often they watched YouTube videos, and how often they used YouTube for learning (the *YT4L* row). Regarding formal training, 49.5% reported no formal training, 39.1% reported some training, 42 participants (9.1%) reported "quite a bit of training", 8 participants reported a lot of training (1.73%), and six participants (1.3%) reported significant training. The most common type of training was received in high school (225 participants), followed by training at university (9 students), practice with feedback (52) and other types (29). The examples If the latter category include speech and drama, public speaking courses, debating workshops, scouting and training in the English as the Second language courses.

Table 1: Survey 1 data (* and ** denote significance at the 0.05 and 0.001 level respectively)

	All (463)	**Constructive (150)**	**Passive (153)**	**Inactive (160)**	**Significant**
Male	333	90	116	127	
Female	128	59	37	32	
Gender - Other	2	1	0	1	
Age <30	455	149	147	156	
Age 30+	8	1	6	4	
Native	385	122	127	136	
Non-native	78	28	26	24	
Training	1.67 (0.81)	1.66 (0.78)	1.69 (0.81)	1.66 (0.85)	
Experience	2.19 (0.84)	2.3 (0.84)	2.13 (0.83)	2.14 (0.85)	
YouTube	4.11 (1.08)	4.06 (1.07)	4.13 (1.04)	4.13 (1.13)	
YT4Learning	3.15 (1.12)	3.15 (1.1)	3.25 (1.09)	3.04 (1.15)	
Task Value	3.89 (0.66)	3.96 (0.59)	3.88 (0.68)	3.84 (0.69)	
Self-Efficacy*	**3.59 (0.64)**	**3.68 (0.65)**	**3.61 (0.63)**	**3.48 (0.64)**	**F = 3.82**
Academic control	4.11 (0.57)	4.16 (0.58)	4.09 (0.51)	4.09 (0.62)	
Intrinsic motivation	3.68 (0.61)	3.77 (0.58)	3.64 (0.62)	3.64 (0.64)	
Extrinsic motivation*	**4.07 (0.67)**	**4.19 (0.64)**	**4.03 (0.66)**	**3.99 (0.68)**	**F = 3.63**
Effort Regulation**	**3.45 (0.67)**	**3.58 (0.67)**	**3.52 (0.63)**	**3.25 (0.67)**	**F =11.13**
Rehearsal	3.08 (0.74)	3.17 (0.7)	3.03 (0.78)	3.06 (0.72)	
Organization	3.11 (0.92)	3.25 (0.89)	3.03 (0.94)	3.05 (0.91)	
Elaboration	3.59 (0.67)	3.67 (0.66)	3.55 (0.65)	3.55 (0.69)	
Self-Regulation*	**3.22 (0.49)**	**3.29 (0.51)**	**3.25 (0.49)**	**3.14 (0.46)**	**F = 3.79**

Regarding experience in giving presentations, 304 participants reported giving project presentations, followed by coursework presentations (141), seminars (47), conference presentations (19), pitching an idea (108), outreach (14), presentations to a general audience (196) and other types of presentations (55). There was no difference between the categories on how often they watched YouTube videos, or how often they used YouTube for learning.

The 46 MLSQ questions used the Likert scale from 1 (lowest) to 5 (highest). The responses were summarised into 10 dimensions reported in Table 2. Using one-way ANOVA, we identified significant differences between the categories on four dimensions. The Tukey's HSD correction identified that Constructive participants had significantly higher scores in comparison to Inactive participants for Self-Efficacy, Extrinsic motivation and Self-regulation ($p < .05$ for all three dimensions), as well as for Effort Regulation ($p < .001$). Furthermore, there was a significant difference between the scores of Passive and Inactive participants for Effort Regulation ($p < .01$).

Student engagement

Table 2 presents data about students' engagement. The *Videos Watched* row reports the average number of videos watched by students, with the standard deviation in parenthesis, as well as the range. Please note that some students watched videos multiple times, therefore the maximum number of videos was greater than eight. There was a significant difference on the number of videos watched by the three categories. The variances for the Constructive and Passive categories on the number of videos watched were equal (as identified by the Levene's test); the number of videos watched by Constructive participants was significantly higher than that of Passive participants (two-tailed $t = 6.95$, $p < .001$).

Table 2: Engagement of the three categories

	All (463)	Constructive	Passive	Inactive	Signif.
Videos Watched	4.62 (4.86)	8.69 (4.43) [1,22]	5.46 (3.63) [1,25]	0	$F = 281.09$ $p < .001$
Comments	2.44 (6.39)	7.53 (9.38) [1,75]	0	0	$F = 100.89$ $p < .001$

Only Constructive participants commented on the videos. Table 3 presents the distribution of comments over videos. The participants commented on all videos, but commenting frequency was higher for shorter videos (Figure 3, left).

Table 3: Comments/ratings per video. The Open column shows the number of comments available for rating. The Rating column shows the number of times comments were rated.

Video	Length (s)	Comments	Frequency	Open	Ratings
Tutorial 1	174	161	0.93	108	638
Tutorial 2	457	144	0.32	94	310
Tutorial 3	355	181	0.51	122	401
Tutorial 4	322	154	0.48	95	306
Example 1	203	111	0.55	70	253
Example 2	508	118	0.23	80	294
Example 3	408	141	0.35	92	320
Example 4	205	119	0.58	78	306
Total		**1,129**		**739**	**2,828**

The distribution of ratings over cue time (i.e. the time in the video when a comment was made) is illustrated in Figure 3 (right). There was a significant correlation between the cue time for a comment and the number of ratings it received ($r = 0.3$, $p < .0001$), with the comments close to the start of a video receiving significantly more ratings. This is the consequence of the design of the rating interface, which presents the comments for rating sorted by the cue time.

The analysis of comments indicated learning, with students noticing important elements of tutorials, as well as reflecting on their previous experience in giving presentations. An example comment made using the "I am rather good at this" aspect was: "*I'm quite good at variation of voice, but speak too fast!*" Another example comment tagged with the "I didn't realize I wasn't doing this" aspect was: "*It's important to make sure the first and last 3 minutes are the best. I found this useful, and when doing my presentation I should plan the ending first.*"

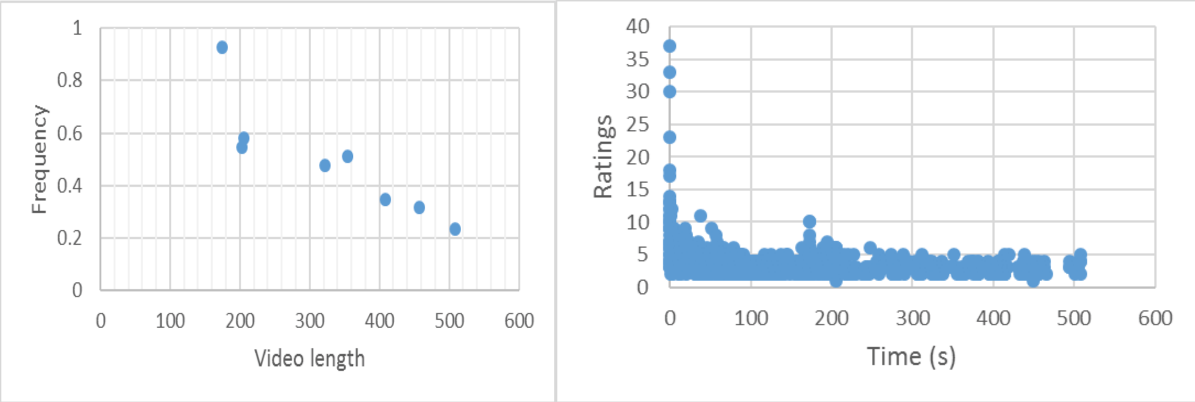

Figure 3: Comment frequency (left) and the distribution of ratings (right)

Findings from Survey 2

Survey 2 contained the TAM and NASA-TLX questionnaires. The ten TAM questions (Davies, 1989) were based on the Likert scale from 1 (highest) to 7 (lowest). Due to space constraints, we only report the average of questions 3 (*Using AVW-Space would enhance my effectiveness when developing transferrable skills*), 4 (*I would find AVW useful in my studies/job), 8* (*If I am provided the opportunity, I would continue to use AVW for informal learning*), 9 (*Using AVW-Space would enable me to improve my transferable skills quickly*) and 10 (*Using AVW-Space would improve my performance considering the development of transferable skills*). We refer to this average as TAM-Usefulness. There were 118 replies from Constructive (mean = 3.75, sd = 1.58), and 96 replies from Passive participants (mean = 3.33, sd = 1.37).The difference in rankings was significant ($t = 2.09$, $p < .05$). It was interesting that Passive participants ranked AVW-Space as more useful, although they did not use the environment as we anticipated.

The NASA-TLX questionnaire required students to report how demanding it was to use AVW-Space, how much effort they invested, how frustrated they felt and how well they thought they performed at the task. The questions were asked separately for commenting on videos, and for rating others' comments. The responses were based on the Likert scale from 1 (lowest) to 20 (highest). The scores provided by Passive participants were significantly higher than those by Constructive students for demand and effort on commenting ($p < .05$), as well as on demand for rating ($p < .05$ for all three comparisons).

Presentation Marks

Out of 904 enrolled students, 836 gave presentations on their projects. The presentations were marked by human tutors blind as to whether a given student used AVW-Space or not. The maximum mark on the presentation was 15. The overall average for the whole 2017 class was 12.62 (sd = 1.44). We compared the 2017 presentation marks to the 2016 class, when AVW-Space was not available. The two-tailed t-test revealed a significant increase ($t = 9.61$, $p < .0001$) in presentation marks for the 2017 class in comparison to the 2016 class (n = 812, mean = 11.86, sd = 1.73), with the effect size (Cohen's d) of 0.44. The only difference between the two courses was the use of AVW-Space.

We found a significant difference ($F = 10.92$, $p < .001$) when comparing the average presentation marks for Constructive students (n = 148, mean = 12.99, sd = 1.44), Passive students (n = 152, mean = 12.73, sd = 1.29) and the Inactive category (n = 155, mean = 12.24, sd = 1.53). The Tukey's HSD revealed a significant difference between Constructive and Inactive participants ($p < .001$), as well as for Passive and Inactive participants ($p < .01$). The difference in presentation marks between Constructive and Passive students was marginally significant ($p = .09$).

Conclusions and future work

The students who used AVW-Space received significantly higher presentations marks in comparison to their peers. There was also a marginally significant difference in presentation marks for Constructive students in comparison to their peers who watched the videos passively. The analysis of the profile data showed that constructive students have higher metacognitive and learning skills; this findings is consistent with previous research findings showing that students with lower levels of self-regulation use educational technology less effectively (Gašević, Mirriahi and Dawson, 2014). We also discovered a significant improvement in presentation marks in 2017 in comparison to the 2016 class, where the only difference was the use of AVW-Space. Overall, these results demonstrated that interacting with AVW-Space was beneficial for students. However, not all students used AVW-Space, and some who used it have not behaved in a constructive way. In our future work, we will enhance the environment to provide adaptive feedback and support during learning.

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Educats: A Community of Practice

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT A STEM education community of practice (CoP) – Educats - has been established at a large university in Australia. This small, local CoP is comprised of postgraduate students, postdoctoral and professional staff in the Faculty of Engineering and Faculty of Information Technology. Wenger (2011) defines CoPs as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly". The shared passion in Educats is better teaching and better learning of STEM subjects in higher education, particularly concerning constructively aligned, outcomes-based education. This paper details the conception and development of this CoP, and addresses the implications on research; teaching practice; pedagogy and identity.

PURPOSE This paper describes the structure of Educats, the activities and achievements thus far and the implications on professional identity, research, teaching practice and personal well-being.

APPROACH Educats is a self-organised CoP comprising of education-focused early-career researchers from STEM disciplines. Members regularly participate in professional development events and social activites. In a semi-structured interview, members reflected on their involvement in the CoP and the influence that their involvement has had on their development and progression as early-career researchers.

RESULTS All Educats members reported individual benefits to their research, teaching, and professional development or personal well-being. Members have improved in research skills as a result of participation in external professional development activities such as training programs and conferences. Other members have initiated their education research and education-focused career path as a result of their involvement and through the support exchanged within the community. Nearly all members reported that their involvement with Educats has benefited their personal mental and physical well-being. Educats has attracted great interest from non-early-career academics and senior university staff with its contributions to teaching and learning becoming increasingly evident within the institution.

CONCLUSIONS The experiences and achievements shared by Educats members thus far demonstrate that a small, local non-hierarchical and self-organised CoP can offer immense individual benefits and significant contributions to teaching and education research in higher education. Additionally, such a CoP has proven to be a great social and support platform for early-career educational researchers.

KEYWORDS Community of practice; early-career researchers; scholarship of learning and teaching; professional identity

Introduction

A community of practice (CoP) – Educats - has been established at a large university in Australia. At time of writing, this small, local CoP is comprised of postgraduate, postdoctoral and professional staff from STEM disciplines. The purpose of Educats is to support its members in their development as early-career researchers (ECRs) and educators through social interaction, discourse, group reflection and practice in pedagogy. Educats is self-organised, non-hierarchical and cross-disciplinary, with social interaction being the significant motivation for involvement and active participation in activities. All members demonstrate individual expertise in educational areas such as blended learning and reflective practice and combine their expertise to drive evidence-based teaching practices in STEM education. The mission of Educats is twofold: the first being continuous improvement in teaching practices that aim to have a positive impact on student learning, the second being outputs in educational research and scholarship of teaching and learning, with dissemination of research outcomes that make a societal contribution in STEM education.

This paper describes the formation and structure of Educats, the activities and achievements thus far and the implications on professional identity, research, teaching practice and personal well-being. The research question at hand is: what are the implications of membership in a CoP on the teaching; research; professional development and personal well-being of ECRs?

Context

Educats was initially formed as a hub for education-focused postgraduate students in Engineering to support each other in their research. Since then, it has evolved to include undergraduate (adjunct), postdoctoral, early-career academic and professional staff across two faculties (engineering and information technology). A strong bond was established amongst members from their shared appreciation for cats, gifs and memes. The name Educats is thus derived from a combination of the words 'education' and 'cats'. Undergraduate student adjunct members of the group are called 'Edukittens'. ECRs wishing to join the CoP do so via personal invitation by an existing member. The candidate undergoes a vetting process in which existing members check the candidate's professional profile (LinkedIn), social networks (Facebook) and relevant experience or expertise (teaching and research) for alignment with the CoP. Potential members are identified from the combined social and professional networks of existing members.

Communications

The primary medium of communication among Educats is Slack, a social and team management platform (Slack, 2017). At the time of writing, there are six chat channels to streamline communications (Table 1) on specific topics such as professional development events or conferences. Slack is the main platform through which weekly lunches are organised and is additionally a space for social interaction among members.

Professional Development Activities

Educats members attend a variety of professional development activities as a group. These professional development activities expose members to current and best practices in teaching and research and help members to develop their teaching practice and research skills. Three existing members are currently participating in an eighteen-month long training program for higher education research organised centrally (non-faculty specific) by the university - the Higher Education Research (HER) Program. Members have attended training workshops for questionnaire design (research); peer evaluation (teaching) and events for networking and sharing of pedagogical best practices. Attendance at educational conferences is particularly important within Educats. Conferences attended at time of writing include: the 2017 Learning and Teaching Conference at our university and the 2017 Australian Conference on Science and Mathematics Education (ACSME, 2017). Members have also attended externally facilitated education-focused events, these included seminars on: the current status of learning analytics; motivation, commitment and wellbeing in secondary teaching; and developing education research practices at the faculty level. Two members attended a week-long winter school on education research facilitated by the Australasian Association for Engineering Education (AAEE). The significance and impact of these activities is discussed later.

Table 1: List and description of the Educats' Slack channels

Channel Name	Description
# aaee	Preparations, discussions and updates relating to the upcoming AAEE conference
# askacat	Help/feedback/advice from members about teaching practices, pedagogies and student experience
# events	Information on upcoming seminars; workshops; training courses; conferences and other education-focused events on and off campus
# general	Discussions, articles, other multimedia relevant to education research and practice
# random	Weekly lunch communications; meme sharing; chit chat
# ratherbehere	Travel and holiday photos from Educats members - places we'd all rather be than at our desks!

Event Organisation

A primary function of Educats is to organise and facilitate professional development events for the CoP and the wider academic community, both as individuals and as a group. The development and delivery of these events contribute to members' professional development and faculty service. One member of Educats has developed and delivered comprehensive training modules on implementing a formal peer evaluation system. Two members worked together to develop and deliver a training module on aligning assessment with learning outcomes (the latest in a series on constructive alignment for outcomes-based education). These training modules are recognised by the central university staff development unit and count towards the professional development employment requirements for all staff members.

Teaching and Pedagogy

There is diversity in discipline, teaching experience and pedagogy expertise within Educats; this enables members to take advantage of each other's strengths to collaborate by developing teaching practices, educational technology and enhancing pedagogies. The range of disciplines and backgrounds of Educats members include: educational design; aerospace; chemical; electrical and mechanical engineering; and computer science. The various teaching roles and experience of Educats members include: tertiary teaching associate (TA) (2-7 years); lecturer (1-2 years); teaching support leader (3 years); non-tertiary teaching (4-7 years) and research supervisor (1-3 years). The fields of pedagogy expertise within Educats include:

- learning management systems
- teaching/learning content development
- professional accreditation
- assessment and evaluation
- constructive alignment (Biggs and Tang, 2011)
- undergraduate critical thinking development
- active learning
- note taking
- flipped classroom
- curriculum design
- audience response systems (ARS)
- student engagement
- teamwork
- peer evaluation

The diversity in discipline, teaching experience and pedagogy expertise provides an environment in which members exchange knowledge and skills that ultimately enhance the quality of teaching and learning at the university.

Research

All Educats members undertake education research projects - either for their postgraduate studies or for their academic career development. The CoP enables members to support each other in their individual education research and also facilitates collaboration among the group. Members discuss aspects of their research through Slack and during weekly lunch meetings. Examples of discussion topics are: education theories; epistemology; data collection methods and data analysis techniques. The researchers regularly meet to collaborate on research projects. These include: writing conference papers; developing educational technology; developing methodology and delegation of research tasks such as data collection and analysis. Peer review is a significant aspect of the research activities within Educats. Members regularly participate in peer review of other members' academic writing, examples of which include: research proposals; literature reviews; ethics applications; conference papers and grant applications. Members also share within the group knowledge and insight gained from their respective research supervisors and education research mentors. Discourse, collaboration and peer review within the group has enhanced members' quality of education research; this shall be discussed later.

Social Activities

Social activities are an important aspect of engagement within the CoP; these activities provide the foundation upon which members strengthen their sense of belonging in the CoP and build interpersonal relationships with like-minded people. There are two primary social events on the Educats calendar: weekly lunches and end-of-semester (EoS) celebrations. Weekly lunches on campus are a valuable opportunity for members to discuss ongoing teaching and research progress. Not all members attend weekly lunch due to individual teaching and research commitments. In Educats, there are no repercussions for lack of attendance; though in any given week, lunch is attended by at least three members. Examples of lunchtime discussion topics are: conference planning; event planning; faculty and departmental news; active learning teaching practices and classroom anecdotes. Potential members being considered for addition to the CoP are invited to lunch so that existing members can further evaluate whether the candidate will be suitable for the CoP. EoS celebrations (e.g. nacho parties) allow current Educats members and affiliates to unwind, socialise and share personal highlights of the semester. These events allow members to strengthen interpersonal relationships within the CoP; the implications of the social aspect of Educats is discussed later.

Theoretical Perspective

The operations of Educats and the structure of this study is primarily informed by Wenger's (1998) community of practice. Wenger defines CoPs as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly". Educats is aligned with those CoPs within higher education institutions that exist with the purpose of promoting the Scholarship of Teaching and Learning (SoTL) in Engineering Education. Educats identifies with the definition of SoTL as phrased by Mann and Chang (2012) to include three main activities:

1. Engagement with the existing knowledge on teaching and learning.
2. Self-reflection on teaching and learning in one's own discipline (often involving education research).
3. Public sharing of ideas about teaching and learning within the discipline.

CoPs in universities typically focus on specific topics in higher education; examples include blended learning, learning analytics, education research. Members in these CoPs are generally motivated by the potential for professional development and networking. Educats places stronger emphasis on social support and a sense of belonging to engage its members. Educats members revel in opportunities to interact with each other - people to whom they can relate on a personal (e.g. cryptocurrency and fantasy fiction) as well as professional level. These unconventional aspects about the Educats CoP act as the social bedrock for the group's structure and operations.

Wenger (1998) outlines three structural characteristics of a CoP as Domain, Community and Practice. The Domain is the shared interest to which members commit and the shared competence that distinguishes members from other people. For Educats, the primary domain is pedagogical practice in STEM education, with a sub-domain being the workings of a university including administration, student services and university politics. The Community is the activities, relationships and sharing of ideas and knowledge between its members. In Educats, this is a collection of ECRs and academics who are passionate about creating positive impact in STEM education. The practices are outcomes-based STEM education and education research. It is also the shared resources (experiences, stories, tools, pedagogies) which empower members to succeed in their respective roles as educators and researchers.

Method

All existing Educats members (seven) participated in a semi-structured group interview roughly six months after the CoP was first established. The interview questions prompted members to reflect on how their involvement with Educats has influenced their teaching, research and personal well-being. Members also provided demographic data regarding their roles, teaching and research experience and expertise. The group interview was audio recorded and transcribed, and themes were uncovered according to the categories outlined in the research question. Approval from the university's Human Research Ethics Committee was sought and granted prior to the interviews and consent was obtained from participants (project ID: 10809).

Results and Discussion

Analysis of interview responses revealed the prevailing themes to be: formation and citizenship in the group; implications on education research and teaching practice; professional development; social engagement and personal support. These themes are discussed in the following sub-sections.

Formation and Citizenship

Educats members have developed a strong sense of community and citizenship since its formation. Enthusiasm, participation and engagement in discourse and activities has increased significantly. Those members that were highly enthusiastic at the beginning have remained so, while those who were shy or nonchalant at first now demonstrate strong engagement and interest. One member who described themselves as an introvert said at the beginning: "*I'm just a lurker; don't mind me*."; this member has since helped to develop new capabilities in an audience response system for teaching large classes at the university; this member has also been instrumental in developing the branding of Educats by commissioning the design of a logo for the CoP. When asked about the reason behind the positive shift in interest and engagement, this member shared that it was related to their career aspirations which had shifted from discipline-based engineering research to teaching and education research.

There is a unanimous sentiment that members are glad to be amongst a community of like-minded people who demonstrate a genuine interest in enhancing education at a research-intensive university. Several members highlighted that being able to brainstorm on teaching practices and research projects with others in the community has been highly valuable and beneficial. When asked what the purpose of Educats is, members were unanimous in saying that it is "*having people to bounce ideas off*"; "*having people that you can collaborate on research with*"; moral support; and exchange of knowledge and expertise.

Members were highly appreciative of having a community of people who share their enthusiasm for education and teaching; one member said:

> *"I can be as passionate about teaching as I want and it would be okay...it was acceptable, whereas I wouldn't have that feeling outside of the group."*.

Another member likened the group citizenship to that of a technical engineering research group:

> *"I haven't had this since I worked in a research lab... it's people to have lunch with, it's people to talk to about your work who are at a similar stage of their career to you and who are working on similar issues but not the same problems".*

Perhaps the most distinguishing feature of Educats as a CoP is that it rejects any notion of hierarchy and power-difference. This is exemplified in one member's comment:

> *"there's no power differential in this group, it's a very flat structure. It would be very different if we had senior academics in this group; it may feel like we had to defer to them whereas we can generate our own ideas and not be influenced by what senior people are going to think of us so it's nice to have peers or equals to talk to".*

This member also added that Educats

> "*is not a work group; it is more about everybody contributing equally and bringing something to the table"*.

The community citizenship provides an inclusive place for members to express their ideas and opinions and learn from one another on equal footing. The absence of a hierarchy and power difference in the community encourages all members to participate and contribute equally.

Influence on Education Research and SoTL

Educats has played a critical role in catalysing education research projects among its members. Members all agreed that they would not have participated in certain events (seminars; workshops and conferences) and programs (AAEE Winter School and HER program) were it not for the encouragement and support from other members. Involvement in Educats has initiated two members' education research and encouraged members to make submissions for the annual AAEE conference. One member felt that the group may not have made as many submissions to this conference without the reciprocating encouragement and support amongst members.

Peer review and regular feedback exchanged within the community has enabled members to develop their education research knowledge and skills. Frequent peer review amongst members have been highly beneficial for ethics applications; questionnaire design; developing data collection methods and general academic writing. Members build upon education research knowledge by regularly contributing to a cloud repository of literature; education jargon; research methods and pedagogies. Knowledge and skill development through peer review, feedback and knowledge transfer have helped members to develop their confidence in education research and to overcome feelings of imposter syndrome.

Raising awareness for SoTL is another purpose of Educats and in doing so the community has gained 'notoriety' amongst various faculties and senior staff at the university. One member stated that the purpose of Educats is "*to share experiences, generate awareness and promote educational technologies and techniques within the university or within the faculty*". One member that works closely with senior staff informed the group that Educats is known amongst Directors of Teaching, Associate Deans and staff from the Office of the Deputy Vice-Chancellor and Vice-President (Education). This 'notoriety' has helped generate further awareness of the growing significance of teaching and pedagogies in STEM. A reputation within the university will also help Educats to obtain support and funding to enable education research outputs and enhancements in teaching and pedagogies.

Influence on Teaching and Pedagogy

The diversity in discipline, teaching experience and pedagogy expertise has enabled Educats members to exchange feedback, insight and knowledge in their roles as teaching associates, lecturers and supervisors. Consequently, members have been able to improve in specific areas in their roles. There is exchange of feedback and insight between the postgraduate students and members that have research supervision duties. This exchange produces two outcomes: 1) supervisor members learn about effective supervision practices so that the they can better understand and cater for the needs of their students and 2) postgraduate members develop an understanding of supervision from the supervisor's perspective which enables them to strengthen relations with their own supervisors. There is exchange of feedback and insight on teaching between members with TA and lecturer roles. One TA in Educats reflected that through discourse and interaction with the lecturers and more experienced TAs, they had gained confidence in approaching the class and students. Another less experienced TA remarked that they had become "*far more aware of diversity in student cohorts"* and that it had helped them to better support the teaching and lecturer in their unit.

Feedback from TAs and lecturers on the use of ARS prompted one member to develop new features in the ARS that they developed as part of their PhD which is used extensively at our university. One member shared with the group that they had implemented another member's recommendations on engaging women in STEM. The member with expertise in female engagement reflected: *"it was great to see someone being so receptive of work that I'd done"*. One member reflected that the training modules on teamwork and peer evaluation developed by another member had been very well received by university staff. The training modules have been attended by over 100 educational staff and there has since been an uptake of better pedagogical practices on teamwork and peer evaluation. This was evidenced by a significant increase in the number of users of the peer evaluation system and positive feedback from students.

Influence on Professional Development

Professional development is a core focus for the ECRs who make up Educats. All members reported that they had attended more seminars, workshops and conferences as a collective with other members of Educats and that they were not as likely to have attended these as individuals. Members have shared with the community knowledge and insight gained from participating in professional development activities. This has resulted in a wealth of knowledge and resources on many topics relevant to research, teaching and pedagogy and is shared within the community via Google Drive. These resources are easily accessible to members and enables the community to build upon existing knowledge and learn from others.

Educats is a community which aids the development of members' professional identity. Two members have been inspired to transition from discipline-based technical research to education research and pursue education-focused career paths. This is exemplified by one member's reflection of their transition from lecturing to educational design:

> *"It's helped me to define my career path a lot more because even though I'm a lecturer and as a PhD student in the past, you would think being a lecturer is like the holy grail. I've actually found that it's not really for me; I don't have the right personality for it and so through the Educats I've learnt that there are other career paths that I can take which embraces my teaching passion and it's actually quite nice to be guided in that sense"*

Members have reported that they have found Educats to be a safe and inclusive environment to express themselves as professionals without apprehension of judgement. One member reflected on the sense of validation they felt within Educats:

> *"It's more a case of finding a group of people who would take my expertise seriously and not talk down to me because occasionally what happens is that academic staff would consider themselves superior even though they're not doing a great job of something that you're trying to teach them to do and it's purely just because of their mode of employment."*

These sentiments demonstrate that a local CoP such as Educats can play a significant role in the professional identity and development of ECRs.

Social Support and Personal Well-being

The social support exchanged in Educats has been beneficial to members' personal mental and physical well-being. All members valued the weekly lunches as an opportunity to take a "*mental break"* from their research or teaching. This is exemplified in one comment:

> *"Without these Thursday lunches it would just be "eat it at your desk" and having a group to come and do that with instead of having your lunch at your desk is probably one of the best things about this group."*

When asked how participation in Educats has influenced their personal well-being, nearly all members shared anecdotes on how this CoP has benefited their mental health. Two members highlighted that Educats helped to lessen feelings of isolation in their respective divisions, as exemplified in one member's anecdote of an instance of workplace conflict: "*without Educats… I would have physically been a lot more isolated, I would have been in my office a lot more if it wasn't for you guys*". One member spoke of the support and advice they received from other members regarding a difficult transition between universities and described that support to be very useful, valuable and "*crucial in this transition period".* Another member reflected that they are now better able to confront their emotions in personal issues as exemplified in their comment:

> *"We've come out of engineering where no one ever talks about their feelings and I feel like this group has really helped me to confront some of that stuff and really grow as an individual, grow more mature and to be able to handle those kind of situations better in my mind."*

One member shared that they had been inspired to participate in regular physical activity for health and fitness upon hearing about the fitness regimes of other members in Educats. This member reflected that:

> *"I find my PhD life is often very stressful. Participating in Educats has given me a valuable resource for help and support. I have spoken to members of the group multiple times about managing stress and finding a healthy life balance. In fact, I now take part in weekly exercise as a result of my conversations with the cats."*

These anecdotes demonstrate that participation in a CoP like Educats is beneficial to members' personal mental and physical well-being. Members' positive responses indicate that a CoP that serves both professional and social purposes can empower members to lead a more balanced lifestyle and achieve personal growth. The personal well-being of ECRs is often not the subject of faculty attention despite its significant impact on the quality of teaching and research at universities, as exemplified in the experiences within Educats. Members derive a collective identity and a strong sense of belonging from their involvement in the research, teaching and professional development aspects of the CoP. The social and emotional support exchanged within Educats reinforces and strengthens this collective identity and sense of belonging.

Upcoming Activities

Educats are facilitating the upcoming inaugural Faculty Education Retreat, bringing together education-focused members of staff from across all the departments in the Faculty of Engineering. The group collectively designed activities with set learning outcomes which included round-table skill-sharing sessions, Lego ideation, and the development of a grass-roots plan to achieve the faculty's strategic goals for learning and teaching.

Conclusions

A collaborative, non-hierarchical, self-organised community of practice has been established for education-focused ECRs. This community focuses on development of members' education research; teaching, pedagogies and professional identity. This is achieved through participation, development and delivery of professional and social events. Involvement in this community has provided members with a professional and social identity and a strong sense of belonging. This is reflected in new research outputs; new collaboration in teaching and pedagogy; continuous professional development and improved personal well-being. A CoP like Educats is recommended for ECRs to support their professional and personal development. A sense of locality, proximity and social rapport is recommended for such a CoP. Ways in which ECRs can establish their own local CoP include: networking at local conferences; education-focused events; local education-focused bodies and postgraduate associations.

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Engaging prospective students with Mechanical Engineering

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SESSION C4: The role and impact of engineers and the engineering profession in the wider community

CONTEXT

With more Australian engineering degrees adopting a common first year model, there is significant opportunity for specialisations to promote themselves to students in order to increase their enrolments. Against a backdrop of increased competition to attract students and adverse media attention on mechanical engineering with the collapse of the automotive manufacturing sector in Australia, the Mechanical and Aerospace Department from a Melbourne based university considered it imperative that a more concerted effort be made to promote mechanical engineering in the extra-curricular space. While the pedagogy of engagement within the context of the classroom is widely documented, few works focus on how these techniques translate to engaging students beyond their normal studies. Thus, recommendations from the literature on learning and engagement can be made to inform a generic activity design. However, the adaptation of these for enhancing student understanding of a specialisation of engineering in an engagement purpose is relatively uncharted territory.

PURPOSE

This research describes the design of a modular and multifaceted engagement activity, informed by literature on engagement pedagogy. Furthermore, the research details how this was applied to change preconceived notions of what mechanical engineering is, for a cohort of first year students prior to their engineering branch selection.

APPROACH

Recommendations from the literature on learning and engagement were researched and collated to form a generic set of engagement activity design requirements. These were used to develop a mechanical engineering engagement activity (MEEA). The activity task, inspired by Theo Jansen's walking machine "The Strandbeest", was designed to highlight various aspects of mechanical engineering, and draw links to existing unit learning outcomes in the degree. The MEEA was subsequently implemented and a mixed method approach to surveying participants was utilized.

RESULTS

An increase in the self-reported understanding and appreciation of the scope of the mechanical engineering discipline was seen for students who participated in the MEEA. Results indicate that there was an increased female interest and representation in the MEEA.

CONCLUSIONS

The implementation of the MEEA resulted in a greater understanding of the breadth and variety of careers available to mechanical engineering graduates. It can be suggested from this that scholarship of learning and teaching can be successfully applied in the engagement space.

KEYWORDS

engagement, first year, branch selection, discipline selection, common first year

Introduction

In 2015 a prominent Australian University changed the structure of its engineering degree significantly to incorporate all branches in a common degree structure. Previously, the aerospace, mechatronics and environmental engineering streams were standalone degrees. Consequently, there was more opportunity but also more competition to attract students to each specialisation. Similarly, the discipline stream units were merged into new design themed core units which encompassed elements of each branch.

Mechanical engineering is commonly associated with cars due to the likeness with mechanics. While classical and many modern mechanical engineering roles do involve cars, there is a whole host of opportunities which lie outside of this trope. By redefining mechanical engineering as involving the study, analysis and design of anything that moves or is subjected to forces or loads, it places emphasis on the broader context which mechanical engineers can exist in. This is particularly important for attracting a diverse group of students whose interests may fall outside of this stereotype and may be unaware of the broader roles of a mechanical engineer in society. Furthermore, engineering in itself is typically viewed as an overtly male dominated field (Smeding 2012, Ceci et al. 2007, Cheryan et al. 2015). While the numbers of males still outweigh those of their female counterparts, the number of females in engineering and mechanical engineering are slowly rising (Kaspura, 2015). This stereotype however is grounded in numbers. Engineers Australia documented the number of female engineering graduates as being 15.8% across all disciplines and 7.14% for the "mechanical and industrial engineering" group (Kaspura, 2015). At the university in question this trend is paralleled with approximately 22% female enrolment across all streams and approximately 14% in mechanical engineering (Phimphachanh 2016). These low numbers consequently feedback into themselves as it further perpetuates the misconception that women cannot or should not partake in engineering as reflected by the low rates.

Against a backdrop of adverse media attention on mechanical engineering with the collapse of the automotive manufacturing sector in Australia, it was considered imperative that a more concerted effort be made to promote mechanical engineering in the extra-curricular space. The Department of Mechanical and Aerospace Engineering (Dept. M+AE) chose to develop new engagement workshops to be primarily held during orientation week and in the lead up to branch selection. The Mechanical Engineering Engagement Activity (MEEA) was designed to initialize contact and dialogue between prospective first year students, the Dept. M+AE and current students. With a generic underpinning design stemming from scholarship of learning and teaching, it was intended that the MEEA would attract and engage students, particularly those undecided on a stream of choice. The MEEA aimed to improve students understanding of and familiarity with the mechanical engineering course and careers and to improve enrolment levels for the mechanical engineering stream, along with an increasing proportion of female students. Additionally, it was intended that after implementation at a university level the activity could be deployed wider into the high school engagement space to engage a broader cross section of the community with mechanical engineering and increase visibility of women in mechanical engineering.

Theoretical Perspective

Techniques to Attract Students to STEM

Fun activities have long been used to attract and engage students. In recent years, they have commonly been used as tools to attract students into STEM. They have the largest effect when activities break down complex mechanisms and systems into a simplified and easier to understand framework (Shernoff et al., 2003). It has been shown that hands on activities are the preferred method by high school students to be engaged with engineering (Little et al., 2009). Furthermore, it has been shown that students engage and are motivated most when presented with a challenging problem to solve independently with appropriate support (Shernoff et al 2003). Voluntary student participation in engagement activities has also been positively correlated with improved academic outcomes (Wilson et al. 2014).

Specific Techniques to Engage Female Students

Colours and tones have gender associations in common society, with darker tones and blue hues being associated with males (Cunningham, 2011). Thus by including colours and tones not primarily associated with the male gender, it assists in positioning mechanical engineering as being a more inclusive discipline. Furthermore, it has been shown that female students in particular require strong female influences on career model off (Watt, 2016). Thus, by having a strong female influence in the demonstration and delivery of workshops, students will be more impartial to considering mechanical engineering as a stream of selection.

Method

Generic Engagement Activity Design

An ***active learning*** mode of delivery was selected as most appropriate as it has been shown to be one of the most engaging methods of content delivery for students (Prince et al., 2007; Anderson R et al., 2007; Prince, 2004; Taylor 2014; Shernoff et al., 2003). Tasks were ***inquiry based*** to facilitate ***critical thinking*** and ***problem-solving skill development*** (Shernoff et al., 2003; Prince et al., 2007). A wide range of ***connections*** or links ***with elements of the relevant degree*** were included (case based teaching; Prince et al., 2007). These links were drawn explicitly, by relating activities to specific units or areas of study, as well as signposting how particular skills are further developed over the course of the degree

Sample competency levels were shown to give students an idea of how their capabilities would be developed. ***Activity difficulty*** was set slightly above the expected level of competency (Shernoff et al., 2003). Where dependencies were identified between tasks, ***appropriate scaffolding*** was provided to allow for correct solutions to be implemented before transition to the next task. In this way, ***all groups were paced*** and were able to ***progress at a similar rate***.

A ***multifaceted and modular*** activity was selected, so that it could be deployed in a variety of different contexts. Simplicity in the execution of the activity was desired, such that it could be maintained and delivered by final year university students with ***minimal preparation or training***. To ***ensure program longevity***, a handover process was established. This included storing all designs and teaching materials such that they are permanently accessible.

A ***unique brand identity*** was carefully applied consistently in line with theories on gender neutrality in colour and branding. A ***relaxed, casual and inviting session ambiance*** was carefully cultivated through the use of music and the way the students and staff running the activity presented themselves and interacted with attendees (Gasiewski et al., 2012). Demonstrators were carefully selected, with a preference for people who were ***personable, welcoming and approachable*** so participants felt they were able to freely discuss any predicaments and questions with them (Gasiewski et al., 2012).

MEEA Activity Theme

A walking machine inspired by Theo Jansen's walking sculpture series "The Strandbeest" (Jansen, 2016) was designed using computer aided design (CAD) and manufactured primarily using laser cutting as seen in figure 1.

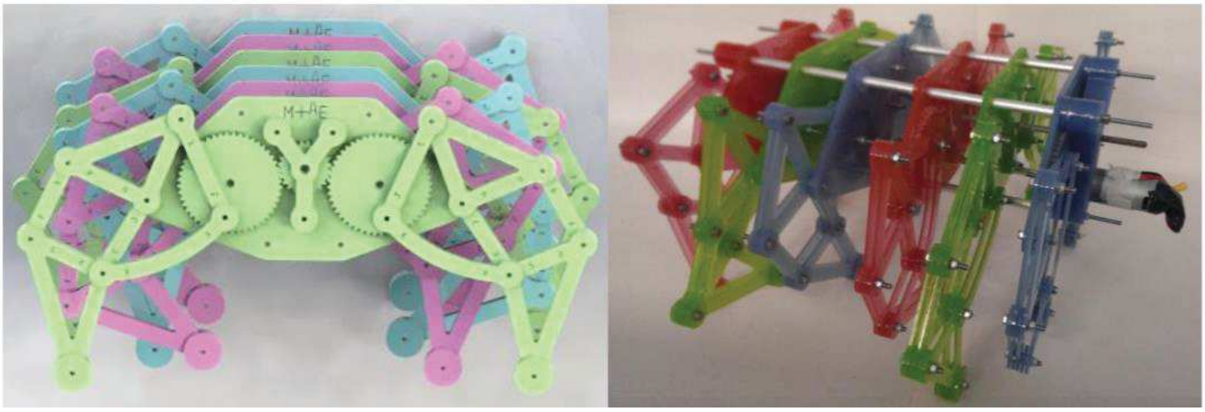

Figure 1: CAD of finalised walking machine design with single motor drive (at rear) showing the redesigned gear train (left) and image of completed walking machine assembly with dual drive capabilities (motors attached at each end).

The walking machine comprising six individual leg assemblies was designed such that it allowed for a range of tasks to be generated from its design. The outline of the leg section could be developed before structural integrity of the “stacked” arrangement explored. Each leg assembly was designed such that it could function independently from the complete assembly. The common “crankshaft” based driving method did not provide this capability, so the crank was replaced functionally with a redesigned gear train which could be driven by an Allen key or long hexagonal rod in the single and total assemblies respectively. Nyloc fasteners were used to prevent self-tightening or loosening of standard nuts due to torques generated during walking. DC gear-reduction motors were incorporated on both a single and dual drive basis with control boxes and mounts being designed and laser cut for each set up. The two-motor design allowed the device to walk forward, backwards and also turn.

MEEA Activity Details

A 3-hour MEEA was designed around the generic engagement activity guidelines described above. Pairs of students were tasked with discovering the correct leg mechanism assembly and stacked arrangement. Students were paced through this by giving solutions at each stage before progressing to the next stage. That is, they were given the correct leg mechanism before proceeding to determining the correct stacked arrangement of a single leg before proceeding to determining the double leg arrangement. After assembly and testing of their single leg set, six of the pairs of students worked together to determine the optimal phasing of the legs to allow successful operation of the walker.

In the session introduction and at each opportunity throughout the session’s activity, elements were linked back to aspects of mechanical engineering and the mechanical engineering course at the university. For example, when discussing manufacturing methods of the activity’s walking machine, 3D printing and laser cutting were discussed including their use on projects such as aerospike engines and 3D printed hands. Another example is when determining stacked arrangement structural integrity and design of structures to react shear, bending and torsional loads without breaking is discussed and linked to the Solid Mechanics unit in which these concepts are covered.

Generic marketing to attract students using images of the walking machine, a brief outline and the session details were used to attract students. A strong female leads and primarily female support demonstrators were utilized unbeknownst to students at the time of registration. A voluntary and anonymous paper survey of participating students was collected at the completion of the most recent workshop set with approval from the university’s Human Research Ethics Committee (Project ID: 10581). This survey employed a mix method approach of non-Likert scale (Select from statement responses), two Likert scales (Very Poor/ Poor/ Average/ Very Good/ Excellent and Definitely Not/ Not Likely/ Likely/ Very Likely/ Extremely Likely) and open-ended questions (Text response).

Results and Discussion

The MEEA was initially implemented for first year engineering students. It has attracted 214 registrations and 196 attending first year students across its offerings in this form. The latest iteration from September 2017, the focus in this paper, saw 41 registrations and 38 attending students (36 respondents, n=36). Of these students, there was 27% female enrolment. This indicates above average engagement with female students when reflecting on the national and university figures for mechanical engineering enrolment which are classically 7% and 14% respectively.

Understanding Mechanical Engineering

When prompted about their knowledge prior to participating in the MEEA as being that they “didn’t know anything about mechanical at all”, “knew a little about mechanical”, “knew a bit about mechanical but was still unsure” or “knew and understood mechanical”, 79% of respondents identified that ***they knew little about mechanical engineering prior to attending to the session***. 97% of participants indicated that participating in the ***MEEA improved their understanding of mechanical engineering*** to some extent, with 45% of responses indicating that it “very much” improved their understanding when provided with the options of “very much”, “slightly better”, “still not sure” and “have no idea”. As a majority of students indicated that they knew only a little about mechanical engineering before attending the session, it reflects the importance of making a concerted effort to engage and educate students on the opportunities within each discipline. Furthermore, due to the increase in understanding of mechanical engineering seen, it can be said that engagement activities may be one avenue to assist students with gaining insight into a discipline’s nuances.

Engagement with Mechanical Engineering

69% of respondents indicated that prior to attending the MEEA that mechanical engineering was “one of” the streams they were considering with 22% documenting that they were “a little” interested in mechanical engineering. This was when presented with the options “I wasn’t interested”, “I was a little interested”, “Mechanical was one option” and “I was definitely planning on choosing mechanical”. ***No participant reported that their level of interest in mechanical engineering decreased as a direct outcome of participation in the MEEA*** when presented with the options of “I am less interested”, “my interest has not increased or decreased”, “I am a little more interested”, “Mechanical is now an option that I am considering” and “I am now definitely planning on choosing mechanical”. 33% of students reported being a “little more” interested in mechanical engineering while 44% identified that mechanical engineering is now an option they were considering for branch selection. As no student’s interest in mechanical engineering regressed and some students reported an increase in interest, it demonstrates that there was no net harm caused by undertaking an engagement activity in this instance. This suggests that for an institution looking at engaging students with a discipline of engineering, engagement activities could be considered as a beneficial method to do this.

MEEA Activity Design

When considering the design of the session itself, 95% of students felt they had enough time to complete the tasks, 97% felt that the session was of a good length and 97% felt that the session was of appropriate difficulty. This was reported when students were prompted if they had enough time to complete tasks with the statements “Yes”, “No, I would have preferred it to be shorter”, “No, I would have preferred it to be a little longer” and “No, I would have preferred it to be much longer”, if the session was of appropriate length with statements “Yes”, “I would have preferred it to be shorter” and “I would have preferred it to be longer” as well as if the session was of appropriate difficulty with statements “Yes”, “No, it was too easy” and “No, it was too complex”. The students who participated in this particular session felt that it had been designed appropriately. This was of importance given the activity difficulty being set slightly above expected competency levels. It could be suggested that students in this cohort responded well to the challenge in the structured environment created. ***All students indicated that they were likely to recommend the MEEA,*** demonstrating the overall satisfaction with the scholarship of learning and teaching choices implemented in this context and instance. Taking the Definitely Not to Extremely Likely 5-point Likert scale where 0 represents definitely not and 5 represents extremely likely, the average score for the likelihood of recommending the session was 4.3 ± 0.7.

Written Feedback

Written feedback demonstrated students enjoyed the problem-solving elements and that the ***best aspect of the MEEA was the hands-on nature of the tasks***. Given students have ample opportunities during their studies in first year to partake in hands on activities by way of three major design projects, one can suggest that this is not merely through lack of opportunity to partake in such activities from which this is being derived. This also bodes well as the mechanical engineering degree incorporates many hands-on projects and experiments. Similarly, students noted that they appreciated the introduction to the mechanical engineering course and the “down to earth” and friendly nature of the demonstrators. These comments reflect many of the scholarship of learning and teaching choices made including the emphasis on inquiry based learning and the ambiance. Furthermore, it emphasises the important of selecting the right people for the task as the demonstrators were often noted as a key influencer on the student experience.

Conclusion

The MEEA attracted a higher incidence of female students than expected, suggesting that careful design and marketing can in some regards, overcome stereotypes presented about an engineering discipline. The MEEA improved students understanding of mechanical engineering significantly, suggesting that scholarship of learning and teaching recommendations for learning and engagement at an academic level are transferable into the engagement space. This is further supported by student respondents indicating that the MEEA was enjoyable and that the best aspects were the hands-on nature of the task and the problem-solving elements, both direct reflections of the recommendations considered.

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Developing student capacity for Startup through integrating engaged, action and threshold learning models with a design thinking framework.

CONTEXT There is a global movement for commercialising innovative ideas, approaches, research and technologies through entrepreneurial models. One of these models is startup. Within an Australian context there is considerable Federal, State and local government support available to assist with this along with opportunities for support through private, Angel Investment and Venture Funds. Many of our students at XXXX Engineering are interested in founding or working for a start up.

PURPOSE What learning model will best support postgraduate coursework students to develop the skills and knowledge they need to be a startup founder or to work for one?

APPROACH In 2016 a new course was introduced in the XXXX Graduate School of Engineering XXXXXXXX Launching a Startup. It was designed to develop student capacity for startup. It integrated engaged, action and threshold and Nexus learning models with an overarching design thinking framework. The course was iterated for a second delivery in T1 2017 and a third in T2 2017.

RESULTS Development of a course to support students interested in founding or working for a startup.
Identify viable student startups generated within the course and feed them into support programs on campus and across the startup ecosystem.
Assist students with existing commercialisable research to assemble a team, make appropriate connections and create their own start up.

CONCLUSIONS With appropriate support and guidance students can identify opportunities for a start up or commercial applications for their research. Once identified these innovations or opportunities can be developed through a structured program to be ready for launch as a start up.

KEYWORDS Innovation, Startup, Entrepreneurship

Introduction

There is a global push to commercialise innovative ideas, research and technologies through entrepreneurial models. One of the models to effect this is startup and it is expected that the startup sector will inform and drive future job and industry creation. Within an Australian context there is considerable Federal, State and even local government support available to assist with startup along with opportunities for support through private, Angel and Venture Fund investment. Many of the students at XXXX Engineering are interested in founding or working for a startup. With a growing global emphasis on developing graduate capacity for entrepreneurship and a corresponding remit from the XXXX Strategy, XXXX Faculty Engineering created a graduate course called XXXXXX Launching a Startup with its first delivery in semester 2, 2016 to a cohort of 40 postgraduate students. The 2 subsequent deliveries have been to cohorts of 54 and 58 respectively. This paper documents the design, development, delivery and iteration of the course. It reflects on some of the course outcomes and how these have informed the iteration of the course content, delivery and overall student experience and outcomes.

Developing a postgraduate course in Launching a Startup

The author has had extensive experience in developing and delivering undergraduate and postgraduate courses and programs in the areas of innovation, collaboration, entrepreneurship and startup. Their preferred approach, in the context of designing a new course, leverages user centred design principles, starting with an understanding of the needs of the students and the desired outcomes of their participation and completion. They evaluate the student experience and use a feedback loop to both co-create and iterate the student experience in a real time, responsive manner.

In the case of this course, the postgraduate students come from the various disciplinary programs across XXXX Engineering and from a range of professional backgrounds and nationalities (up to 21 in one class) providing a professionally and culturally diverse community of peers with a broad knowledge of international contexts of practice. They are the ideal type of cohort to develop a collaborative community of learning with.

The XXXX handbook description

Working on bringing innovative ideas or discoveries into reality, either on your own or internal to an organisation, can be a daunting task. The processes of Innovation, Startup and Entrepreneurship / Intrapreneurship require different skill sets and specialist knowledge and can be very difficult to successfully balance, particularly as an individual. This course is designed to furnish participants with an understanding of these three processes and how they differ yet support each other. Through an innovative mix of learning, teaching and assessment methods students will work in small teams, and with mentors, to identify an opportunity, innovate a solution, design a product or service and develop an entrepreneurial approach to delivering it to. Successful completion of the course should result in participants being ideal Startup founders, cofounders or team members.

Course Aims

The course outline explains that the course aims to develop in students a capacity to identify opportunities for innovation and capitalise on these through intrapreneurial and entrepreneurial models in cross disciplinary teams. It will provide students with the skills necessary to successfully produce and commercialise innovative ideas. It exposes them to industry experts, successful startup founders, key theorists and XXXX staff and researchers who have either innovated, commercialised or supported the process. Through experiential learning, students develop key skills and knowledge to work in the innovation and startup space.

Student Learning Outcomes

The course outline also explains that after completing the course, students should be able to:

- apply disciplinary principles and practices to new or complex environments.
- apply enquiry-based learning and ways of thinking to new disciplinary and/or professional contexts.
- investigate, generate and synthesise complex ideas and concepts at an abstract and/or applied level.
- analyse problems or issues, articulate appropriate solutions and justify propositions and/or professional decisions.
- communicate complex ideas in a variety of formats to diverse audiences.
- demonstrate an understanding of, and the ability to apply, the principles of teamwork and collaboration.
- demonstrate an understanding of international perspectives relevant to the discipline or professional field.

In addition, it states that successfully completing the course contributes to the development of the following graduate capabilities:

scholarship:

- understanding of their discipline in its interdisciplinary context
- capable of independent and collaborative enquiry
- rigorous in their analysis, critique, and reflection
- able to apply their knowledge and skills to solving problems
- capable of effective communication

leadership:

- enterprising, innovative and creative
- capable of initiating as well as embracing change
- collaborative team workers

professionalism:

- capable of operating within an agreed Code of Practice

global citizens:

- capable of applying their discipline in local, national and international contexts

Course Delivery and Teaching Strategies

Whilst some aspects of innovation and entrepreneurship can be learned via traditional methods such as lectures, readings, case studies, literature review and pure and applied theoretical approaches, research on innovation and entrepreneurship education has shown a learning-by-doing (action) approach is more effective. This course integrates the best aspects of both approaches through a strong action-learning focus scaffolded by a flipped-classroom model incorporating current academic literature and industry studies. The course is enriched with engaged learning opportunities from weekly interaction with industry and practicing entrepreneurs to tailored team mentoring sessions. It is also supported with weekly online topics based on the Lean LaunchPad and Disruptor's Handbook methods, which are used by leaders in this space such as Stanford, Berkley and the University of Pennsylvania.

During their project, students form small teams, identify potential business opportunities and utilise enquiry based learning to innovate, create and assess the viability of their product / service / technology and business model. Upon completion of their project, students pitch their ideas and business model to an expert panel which includes potential investors, technical experts, XXXX staff and mentors in Week 13. They also reflect on their learning process through a writing activity due in Week 14.

All materials for the course, such as readings, videos, case studies, compliance and government web links, workbooks, templates and interactive forum activities are provided, in a flipped model, via a learning management system (LMS). Students access these materials at their own pace as their team moves through the development stages of their project.

The face to face components of the course are divided into weekly themes which are grouped into the four stages of the Design Council UK Double Diamond design thinking & innovation model. This is outlined below in Table 1 below.

Stage 1: Discover	**Stage 2: Define**	**Stage 3: Develop**	**Stage 4: Deliver**
Week 1 Entrepreneurship, Intrapreneurship and Startup : Introduction Design Thinking: Identifying opportunities	**Week 4** Customer Development (continued)	**Week 7** Value Proposition & Channels	**Week 10** Partners
Week 2 Tools for Innovation : Lean Canvas and BMC	**Week 5** Innovation workshop	**Week 8** Customer Relationships	**Week 11** Resources & Costs
Week 3 Market Research & Customer Segments & Customer Development	**Week 6** MVP - Minimum Viable Product	**Week 9** Revenue Models	**Week 12** Pitch & Presentation Skills

Table 1: The Double Diamond model as applied to xxxxx

Each week a one hour guest lecture is provided, in line with the weekly theme. These are held as a series of open public lectures called Startup Monday and provide students access not only to industry and sector leaders and successful startup founders, xxxx staff and researchers and disciplinary experts who present, but also to other members of the XXXX, and broader community who are interested in startup, innovation and entrepreneurship and may become mentors, investors or collaborators. The guest lectures are filmed and added to a library of resources that is building over time for all XXXX staff and students to access.

Following each guest lecturer, interactive workshops are held to reinforce concepts through action learning and provide additional examples to the class. Consultation and mentoring also occurs in these workshops and provides opportunities for targeted feedback and review. The workshop time is used to form, bond and progress teams through the development stages of their startup.

Assessment Strategies

The assessment strategy allows students to demonstrate their acquisition of skills and knowledge and their ability to apply them in context over time. Care has been taken to develop assessments that acknowledge that risk and failure are almost inevitable in startup and are an important part of the learning cycle. They assess the individual's ability to be a collaborative innovator and entrepreneur, the individual's ability to be a productive part of a team and the team's ability to deliver an outcome together.

Assessment task 1 is individual and split into two parts and is worth 30% of the total grade.

The first part is a communication task in week 1 which asks students to write a LinkedIn style professional profile to position themselves as a potential collaborator, their interests, skills, knowledge, experience, motivation for studying the course, entrepreneurs they admire and any project ideas they might have. They post it in a public forum and they comment on each other's ideas, read each other's profiles and get to know who might be suitable collaborators.

The second part is due in week 14. It is a reflective writing task where students document how they have developed collaboration, innovation, entrepreneurship and startup skills over the semester, how these will be useful in their future careers, and the challenges they have overcome in the course, personally and as a team.

Assessment task 2 is a team activity with 40% and divided into 4 10% parts.

A number of different communication techniques are specified in this series of tasks to develop capacity to use all the types of communication formats that may be required in a startup context. The staged delivery of the task gives teams the opportunity to gain valuable and timely feedback across the delivery of their project from peers and from their instructor.

Task 2a Week 4 Team & Idea Pitch:

Teams pitch their idea and their team to the class in a 5 minute structured presentation. Describing their identified opportunity, why their team is the right one to leverage it based on skills, knowledge, experience and connections, who else they need and where they will find them. They can only use a verbal delivery.

A forum is opened for each team in the LMS and each individual student is asked to provide constructive critique of each of the teams. This provides immediate feedback to the teams and helps individuals develop constructive critique skills. Individual students are also assigned $100,000 to invest in any way they like across the projects. This helps them develop an investor mind set.

Task 2b Week 6 Progress Pitch: Customers and other stakeholders : Business Model.

Teams pitch a more refined idea to the class, validating their startup. They outline who their customers are, the problem they are solving for them and the business model they have chosen to deliver the product / service to them. They are asked to may use any format they feel appropriate and most choose to use powerpoint or similar. They are refining and honing their communication techniques.

Again a forum is opened for each team and individuals are asked to participate in constructive critique of all the teams. Individual students are again assigned $100,000 to invest in any way they like across the projects. The feedback is used by the teams moving forward.

Task 2c Week 9 Progress Pitch: Minimum Viable Product (MVP) and Value Proposition

Teams are asked to prepare a 3 minute video pitch outlining their Value Proposition and what the MVP they will deliver will be. They have all prototyped their MVP by this stage. They specify how they will develop customer relationships and what channels will be used for distribution and fulfilment. They upload the vidoe to you tube or a similar platform and provide a link via the LMS for their peers participate in constructive critique of all the teams.

Task 2 d Week 12 Report: Intellectual Property (IP), Financing and Compliance

Each team generates a report on how they will deal with the compliance and finance aspects of their startup. The resources they need, their cost considerations, their revenue model, their IP and compliance concerns? These are posted in the forum again and each individual is asked to review and critique 5 reports.

Assessment task 3

Task 3 is worth 30% and is due in week 13 it is the final Demo and Investment Pitch:

Each team pitches their startup idea to a panel of industry leaders, investors, peers and XXX staff. They prepare a 5 minute pitch and a prospectus for potential investors. Individual students are again assigned $100,000 to invest in any way they like across the projects.

Applying Engaged Learning, Action Learning, Threshold Learning and Nexus Model to designing the course.

Engaged Learning

Delivering meaningful, engaged learning experiences recognises the changing needs of the 21st century student. Jones, Valdez, Nowakowski, and Rasmussen (1994) have developed a set of eight indicators of engaged learning to guide educators applying it in their practice. The application in this course is described below.

Indicator 1.

Successful, engaged learners are responsible for their own learning. The students in XXXX define their own learning goals through self selecting their projects and evaluating their achievements through peer review and reflective writing. They are solving real problems and developing capacity to be strategic in their learning, sharing and transferring knowledge to solve the problems creatively whilst being collaborative, valuing and having the skills to work with others.

Indicator 2.

Tasks for engaged learning are challenging, authentic, and multidisciplinary. It is a complex task to identify a commercial opportunity, find a product/ service or mixed model solution to it and develop a viable business model to deliver it. The process involves multiple skill sets and occurs over a sustained length of time. The XXXX learning experience is authentic in that it correspond to the tasks of workplaces of today and tomorrow. The collaboration takes place with peers and mentors within XXXX as well as with others outside faculty. The integrated instruction approach used incorporates problem-based learning (through the project), scaffolded by the theory provided in curriculum.

Indicator 3.

Assessment of engaged learning involves presenting students with an authentic task, project, or investigation, and then observing, interviewing, and examining their presentations and artifacts to assess what they actually know and can do. Performance-based assessment has been designed in, particulary with respect to task 2. It is generative involving the students in generating their own performance criteria (through the peer review, reflective writing and investment activities). They play a key role in the overall design, evaluation, and reporting of their assessment. This performance-based assessment strategy connects to curriculum and instruction and is ongoing, representing all the meaningful aspects of student and team performance equitable standards that apply to all students.

Indicator 4.

Instructional models and strategies for engaged learning should be interactive. Instruction in XXXX actively engages the students in interactive workshops, presentations and assessment. Instruction is generative, encouraging the students to construct and produce knowledge in meaningful ways across the structure of the four stages of the Double Diamond model. The students interact generatively with their teacher and peers, involved in teaching each other interactively within and across their teams and as individuals though their weekly team workshop participation and through the peer review processes. This facilitates co-construction of knowledge and promotes engaged learning that is problem, project, and goal based.

Indicator 5.

The learning context of engaged learning requires the ‘classroom’ to be perceived as a knowledge-building learning community where members develop shared understandings collaboratively, and create empathetic learning environments that value diversity and multiple perspectives. There are a number of summative and formative activities across the semester designed to build the learning community and celebrate its diversity. They include a series of icebreaker activities in week 1, the online introduction exercises, a class lunch where everyone brings a traditional dish to share in our lunch break between the guest speaker and the workshops, collaborative problem defining and solving, constructive peer review and entrepreneurial activities.

Indicator 6.

Grouping for engaged learning collaborative work that is learning-centered should involve small heterogeneous teams of two or more students. By framing group formation in xxxxx students are encouraged to form teams of up to five, based on common technology interests and should include a mix of different genders, cultural backgrounds, skills, and disciplnary expertise. This brings a wealth of background knowledge and perspectives to the different team tasks and ensures increased learning opportunities between peers.

Indicator 7.

In engaged learning contexts the role of the instructor in the classroom shifts from information giver to facilitator, guide, and learner. As a facilitator, the instructor provides the rich environments and learning experiences needed for collaborative study and acts as a guide, incorporating mediation, modeling, and coaching into their practice. Often they become a co-learner and coinvestigator with the students. In XXXX the author, through the design of the course, positions themself as a facilitator, co-learner and collaborator. They guide the students through all the resources, materials and activities, facilitate team formation and development, coach the team through the innovation and entrepreneurship process and model the various methods the teams can use in their project based learning and problem solving.

Indicator 8.

The student role in an engaged learning scenario is that of an explorer. Their interaction with the physical and virtual resources, their peers, mentors, collaborators and the instructor facilitates students to discover concepts and apply skills. They are then encouraged to reflect upon their discoveries through observing and applying the thinking processes used by practitioners. They integrate what they've learned and become producers of knowledge, capable of making significant contributions to the learning community. The author provides all the course materials up front for the students to navigate and guides the students to use them in context, designing in opportunities for peers to be experts, explorers and teachers in the teams.

Action Learning

Reg Revan introduced action learning in the mid-1940's as Director of Education for the British National Coal Board, and continued to develop and promote its principles until his death in 2003. Action learning focuses on increasing learning capacity while responding to a real-world challenge in a cross-disciplinary team. The students in XXXX all self-select real-word problems on which to work towards addressing with, technical and entrepreneurial frameworks across the semester. Reflection is an important part of the action learning experience xxxxx students reflect on their own experience, their team's work and the work of their peers. Much of their learning occurs in small, mutually supportive teams, taking advantage of their team members' experience. Knowledge and experience exchange between the team members generates fresh approaches and helps build innovation and learning capacity within the team.

The teams start with a period of strategic questioning of the problem. They set action items and goals aligned to the assessment structure and analyse their progress towards these goals. As individuals and teams they reflect upon, and document, the process and present the outcomes of their work for review.

The team are empowered and trusted with the necessary resources to take on the issue they identify with some guidance and mentoring.

There are six components in an action learning context as illustrated in figure 1 below.

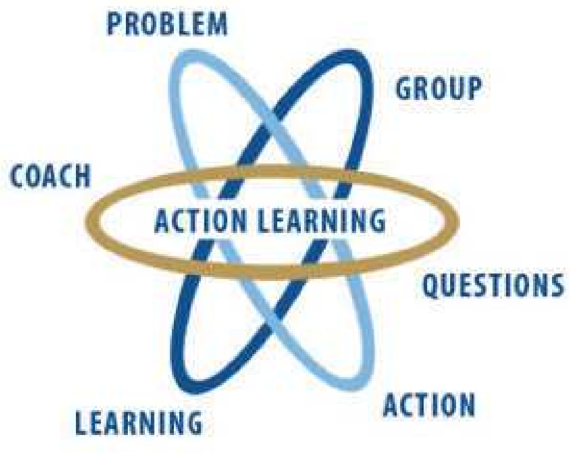

Figure 1: The six components of action learning from https://wial.org/action-learning/

There is a group or team, supported by a coach, who undertake a learning experience whilst solving a real problem.

The context:
Action learning is intended to increase the learning capacity of a team by them resolving a real problem in an organizational context.

The context for the students is to use an enterprise model to address an identified opportunity or problem and to learn about entrepreneurship from this.

The situation:
Action learning begins with a clearly defined organisational opportunity or problem.
The student teams identify the opportunity or problem and set objectives to meet it.
The team is fully empowered to bring the challenge to a successful conclusion.

The team:
Action learning teams comprise members from diverse backgrounds, skills and experience.
The student teams are expected to first define and understand the objective,
then commit their energy and expertise to the team process to address it. They participate as equals, empowered and encouraged to contribute to a collaborative solution. They learn about fellow team members early in the experience through assessment 1a and 2a and some icebreaker exercises in class. This includes backgrounds, range of expertise and skills and how these can contribute to the objective?

Insightful questioning and reflective listening:
xxxx students used design thinking methods partnered with either the Lean or Business Model Canvas to undertake a rigorous enquiry process around the opportunity or problem.

Journaling:
Students record team and personal experiences, research, learnings and insights. The synthesise these records into their assessment presentations and reflective writing.

Action items:
Student team members divide tasks, set timelines, and individuals or sub-groups implement them. Individuals are challenged both to use their range of expertise as well as stretch their approaches to implementation.

Team mid-course reviews:
Across the semester, in line with assessments, the team assesses feedback, discusses progress, deals with problems and sets next stages of their work. They document outcomes and add to the journaling.

Team concluding reviews; institutional review:
xxx student teams and individuals reflect on performance and are provided feedback from peers, their course coordinator, mentors and assessment panellists.

Coaching:
Reg Revan, founder of action learning, believed that team members are their best coaches, facilitators or leaders. By providing structure and opportunity to students in xxxx to develop experience in reflective and group processes, as well as outside facilitators and mentors or coaches to assist the team, much as any resource can be accessed.

Threshold Learning

Threshold concepts sit at the heart of a body of knowledge. They are the fundamental understandings that students need to 'get' in order for core disciplinary knowledge to make sense. In this course there are a number of threshold concepts, but not all are relevant to the entire cohort due to the mixed backgrounds and experience levels they have.

I will give an example from xxxx of each of the five characteristics of threshold concepts and how they are dealt with in the course.

Transformative:

Transformative concepts effect a shift in a learner's perception where their new understandings become part of who they are, how they see and feel. In xxxx one transformative concept is that of the user centred design principle of empathy for the end user of a product or service. Students embed the practice of understanding the needs of the user in order to provide the best solutions for them.

Irreversible:

Irreversible concepts are unlikely to be forgotten once understood and earlier behaviours and patterns are not likely to be returned to. The continual reflective review process develops the student ability to become a constructively critical, reflective practitioner and life long learner.

Integrative:

Integrative concepts expose students to the interrelatedness of concepts they have previously seen as unrelated. In the case of XXXX few students have previously made the connection between the roles of engineers and other experts such as legal, compliance, marketing, communication and design in the innovation and commercialisation process.

Bounded:

Bounded concepts border on new or other thresholds, particularly in interdisciplinary subjects such as XXXX where, in the context of founding a startup the students must consider all of the different disciplinary dimensions of running a small business.

Troublesome Knowledge:

Troublesome knowledge refers to difficult to grasp concepts. For the students in xxxx two areas of troublesome knowledge are. 1. how to develop a business model for their startup. This is addressed through providing a weekly step by step working through the Business Model Canvas coupled with expert mentoring. 2. the need for engineers to immediately solve a problem before checking it is actually a problem and then fully understanding why it is a problem and the various options that could address it. This is solved through requiring the students to validate their business idea and to then test their proposed minimum viable product with users before finalising their solutions.

Nexus Model

The NEXUS model (figure 2 below) describes the processes through which a team of collaborators may progress from the start to the finish of a project and the possible continuation of collaboration through successive future projects. It is the model used to form and guide teams in XXXX. It acknowledges that the collaboration does not always start at the point of NEXUS. It often begins before that point with a courting process which is emulated in XXXX through a number of activities where students share their ideas with their peers in class via LMS and get to know each other through LMS and class based introduction activities. The Nexus Model also acknowledges that working together does not end after one collaboration. If it is successful a collaboration should lead to successive future collaboration(s) of the team or a subset of the team. There may not always be an innovation or an entrepreneurship component to the project. These are treated as overlays.

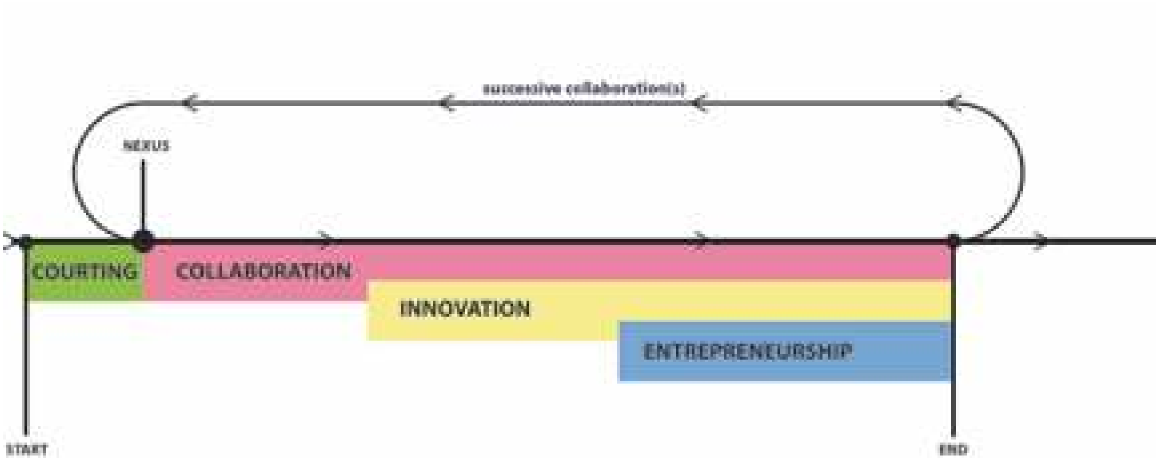

Figure 2: The Nexus Model.

Student Outcomes

For the students, this course is delivered in a very different format to any course they are used to. Feedback suggests that this is good. Aspects of the program they really enjoy include the exposure to, and opportunity to interact with, guest speakers, finding or being assigned mentors, selecting their own real projects to work on, selecting their own teams to work in, having the opportunity to develop a business, hands on workshops, refining communication skills, peer review process, presenting to potential investors, learning design thinking methods and tools, using the business model canvas, access to all the materials via LMS. However, some students indicated they find the self determination in project and team selection daunting and would like them to be assigned.

Many of the student teams continue to work on their ideas, or a modified version of them, after the course is over. Some do so on their own, some move into incubator and accelerator programs internally at XXXX or outside in the broader ecosystem. Some find investment funding. Some take their projects back to their workplace as an internal innovation project. Some teams take their projects and present them internally and externally at pitch competitions and have been successful in gaining prizes and other rewards or support. Some students have taken their projects back home to another country and are still working on them. Some students realise, after the course is completed, that they are not the right fit for startup but enjoyed the opportunity to discover this.

Next Steps

It is the intent of the author to develop this course further to enable it to be undertaken online, by distance students and to be scaled to be able to cater to much larger cohorts. This will require some consideration of how to develop the community of learning experiences in an online context and how to facilitate mentoring.

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Motivating diverse student cohorts with targeted learning material in control engineering

Felix H. Kong, Brian K.M. Lee, Ian R. Manchester

SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

Our introductory control engineering course is found to be difficult by many of our third-year students who come from various engineering streams (e.g. biomedical, aeronautical). To ensure that students come away with a working knowledge of control engineering relevant to their field, it is important to keep this diverse cohort of students motivated. In addition, our course relies on knowledge from prerequisite courses; incoming students may have gaps in this knowledge. Also, some topics may need more clarification outside of lectures throughout the semester.

PURPOSE

The purpose of this project was to better motivate students from multiple streams to engage with course material, and to give students additional help on specific topics that students were unclear about.

APPROACH

We conducted weekly post-lecture surveys, and based on these surveys, produced post-lecture follow-up videos addressing topics that students indicated difficulty with. Additionally, we attempted to motivate our diverse group of students using a stream-specific design project (e.g. a simplified rocket landing problem for aeronautical students, closed-loop insulin control for biomedical students).

RESULTS

Two sources were used for results: the Unit of Study Survey (USS), which obtained general feedback regarding the course, and a Follow Up Survey (FUS) run by the authors. The FUS asked questions specifically about the two new teaching methods mentioned in the Approach. Roughly 60% of the class responded to the USS, while about 10% responded to the FUS.

CONCLUSIONS

Based on student feedback and the authors' own reflections, the videos were well received, and were helpful to students to follow the course and during revision at the end of semester. The stream-specific design projects did appear to motivate students better, but could be improved by a better balance in difficulty and guidance from instructors.

KEYWORDS

Control engineering, Problem-Based Learning

Motivating diverse student cohorts with targeted learning material in control engineering

Felix H. Kong, Brian K.M. Lee, Ian R. Manchester

Introduction

Upper level undergraduate courses and masters level courses in STEM (science, technology, engineering, and mathematics) are often highly technical, and rely heavily on rigorous theoretical concepts. In engineering, it is often difficult to connect to physical intuition and practical insight, which can impede student motivation and interest.

Our introductory control engineering course AMME3500 at the University of Sydney has about 300 undergraduate and postgraduate students from varying streams, including aeronautical, mechanical, mechatronic, and biomedical engineering. In such a large and diverse class, the standard practice of lecturing and giving assignments may not be the best way to keep students motivated. Mills & Treagust (2003), for example, suggest that the conventional 'chalk-and-talk' engineering curricula are overly focused on the technical aspects, providing limited relevance to industrial practice and insufficient design experience. This may prevent students from engaging with the course material. In particular, it may reduce motivation.

As an effort to counteract this, we targeted student motivation in two ways: firstly, by producing videos targeting topics they have identified as being confused about, and secondly, by giving a stream-specific assignment to target students based on interest.

As an upper-level course, our course content builds upon materials covered in prerequisites; if a student fails to understand a basic topic, s/he will struggle to learn topics dependent on it. In order for students to learn effectively, especially in a problem-based learning environment, basic concepts from prerequisite courses must be understood, which in our experience has not always been the case.

Blended learning provides a good avenue for this, in particular online videos, which are available at any time. This facilitates revision at the student's own pace, which can increase student ownership of their own learning (Urdan & Schoenfelder, 2006). Online pre-lecture lesson modules are increasingly popular for teaching STEM related courses, (e.g. Docktor & Mestre, 2014; Chen, Stelzer & Gladding, 2010). However, without student feedback, the topics of such videos must be selected by the teaching staff, which may or may not align with the topics that students need most; we created follow-up videos informed by post-lecture surveys that target specific areas that students have indicated difficulty with.

This is a natural extension of the “flipped” classroom, where content delivery is given during non-contact hours. It reserves contact hours for more interactive work, which can increase the students' sense of ownership towards their own learning (Abeysekera & Dawson, 2015). The sense of ownership is increased by allowing students to participate in post-lecture surveys, to ask for help on particular topics, and to receive additional support on those topics.

Recently, there has been interest in making assignments more relevant to practical engineering problems by making them more realistic, complex, and open-ended; e.g. (Verbič, Keerthisinghe, Chapman, 2017). Our course already makes use of a problem-based learning component in the form of a design project, which can enhance intrinsic student motivation (Norman & Schmidt, 1992). But in such a large cohort, assigning just one problem to all students may leave some students uninterested. For example, a closed-loop insulin pump controller design would be more easily recognized as applicable to a biomedical student than an aeronautical one; vice versa for a longitudinal autopilot controller for an aircraft. As student interest motivates students (Pintrich, 2003), course content is more effective when students are interested, and is better able to relate it to prior knowledge that they may have acquired from other courses in their stream. One way to do this is to put course content into the context of their degree; we created stream-specific assignments to motivate the diverse cohort, one design project for each stream: biomedical, mechanical, mechatronic, and aeronautical.

In this paper we describe the implementation of the stream-specific assignments, the post-lecture surveys, and their corresponding online follow-up videos. We describe and comment on some results about the reception of these new teaching methods, and give a few concluding remarks.

Method

We separate our approach to the stream-specific assignments from the follow-up videos into two sections, below.

Follow-up videos from post lecture surveys

Our approach to video content outside of contact hours was to use them as targeted feedback on specific issues that students struggled with. Through weekly post-lecture surveys on the class forum, we identified topics that students wanted more clarification on. Based on this information, follow-up videos were produced by the lecturer, and were videos addressing topics such as linearization, the Laplace transform, and sketching a Bode plot. Each video was hosted on YouTube, with an announcement containing the links to the videos posted on the class forum. Figure 1 shows the follow-up video for Taylor series, which was a result of students expressing interest in revising the topic of linearization and Taylor series.

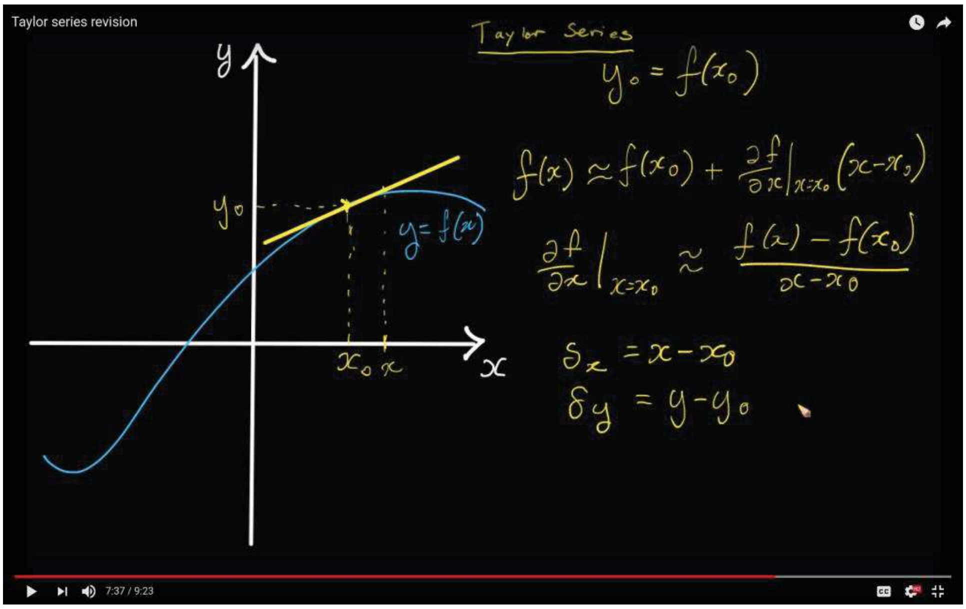

Figure 1: A follow-up video on Taylor Series

Stream-specific assignments

Our approach was to assign a stream-specific design project (e.g. a simplified rocket landing problem for aeronautical students, closed-loop insulin control for biomedical students), and to develop post-lecture videos for specific topics that students have indicated difficulty with.

The design projects, assigned in the second half of semester, were designed as an interesting example of control engineering applied to the context of each stream, shown in Table 1. The assessable material within the design projects was kept the same across all streams, despite the differences in topic. For example, while each stream was given a different nonlinear system, all students were required to produce a linearized model about some operating point. Similarly, while the control design objectives were different between streams, the design methods covered in the course are applicable to any stream. Also, a small stream-specific 'bonus' question was given to each stream, which encouraged deeper thought on the application of the controller design in a practical scenario.

Table 1: Stream-specific assignment topics

Stream	Design Project topic
Biomedical	Control of closed-loop insulin pump
Mechanical	Steering control of autonomous vehicle
Mechatronic	Motion control of 2-link robotic arm
Aeronautical	Rocket first-stage re-entry and landing control

To ensure that the students work on the same model, a Simulink template was provided with MATLAB source code. To prevent any potential discrepancy in workload between different streams, the following structure was used in all questions.

Design project fairness guidelines

1. In the Simulink template is a block for an actuator (e.g. a motor for mechatronics students) with unknown dynamics; all students were required to identify a model of the actuator. The actuator code was obfuscated to prevent modification or easy discovery of model parameters. The actuator model for each stream is second order, stable, and has poles sufficiently far away that there is minimal impact on the plant dynamics, even if the student fails to accurately identify the dynamics of the actuator.
2. The model of the system (e.g. the robot arm for mechatronics students) is given to students, but is nonlinear. All students must linearize this model about an operating condition. The models for each stream have either three or four states.
3. All students must design a controller for the linearized model.
4. All students are encouraged to attempt the 'bonus' question. In bonus questions, the student must conduct additional research to develop a more advanced model (e.g. glucose-insulin kinetics with additional compartmental dynamics), and repeat 2. and 3. on the model. Bonus questions are not necessary to achieve full marks.

To support the integration of numerical calculations into practical intuition, we developed visualizers for aeronautical, mechanical, and mechatronic streams. These simple visualizers helped students understand how the graphs they obtain from simulations relate to real-life engineering problem (e.g. how the graph of yaw angle of a car relate to actual driving). No visualizers were provided for the biomedical stream due to the inherent difficulty of visualizing chemical concentrations within a pancreas.

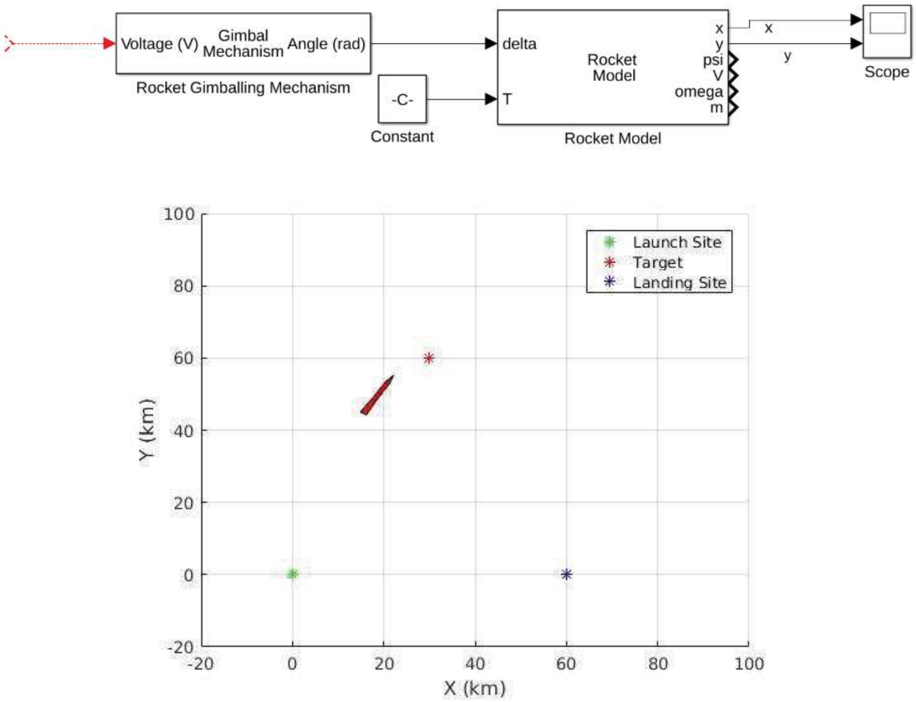

Figure 2: Simulink template from aeronautical stream design project (top) and simple visualization of rocket (bottom).

Results and discussion

To evaluate the effectiveness of these new teaching methods, results were obtained from the Unit of Study Surveys (USS's), and also a Follow-Up Survey (FUS) designed to evaluate the follow-up videos and the stream-specific assignments in particular. The USS run by the university had 190 respondents, while the FUS had 33. As the USS was not designed to evaluate these new teaching practices, for the USS we have restricted ourselves to using only the comments that specifically mention the new teaching practices. On the FUS, students were asked to respond to a number of questions on a Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"); these results are shown in Table 2 (see Appendix).

On follow-up videos

The follow-up videos were evidently very popular, some of them being viewed over 300 times, according to their YouTube viewer counts. When asked what “the best aspects of this Unit of Study” were, many responded on the USS saying follow-up videos were the best aspects. The following are typical comments:

Youtube videos were highly informative and helpful

The small videos on [the class forum] for topics we were struggling for [sic] were very good and helpful and good to refer back to, maybe more of them would be helpful.

I really liked the videos. I feel like those kind of Khan Academy style videos are a lot more effective at teaching concepts. Perhaps you could expand on those and make it a weekly thing which students should watch before the lecture, then use the lecture time more to go through examples and answer student questions rather than go through lecture slides in the traditional format.

I really appreciated the extra videos posted on [the class forum].

... great online content videos posted by [the lecturer].

The suggestion in the third comment is exactly the flipped classroom according to Abeysekera & Dawson (2015), Hereid & Schiller (2013), among others. This suggestion, and related ones, are seen repeatedly throughout the Unit of Study feedback. The feedback closely aligns with the course coordinator's own thoughts on improvements to make to the course next year; next year we plan to utilize out-of-class videos more heavily for information transmission, including some pre-lecture videos that introduce some of the content. Interestingly, while 48% of FUS respondents said that they "strongly preferred" or "preferred" pre-lecture videos over post-lecture follow-up videos, 31% were neutral, suggesting that many were unsure (see Table 2). Based on this information, we may implement both pre- and post-lecture videos in the coming year.

In addition, 82% of FUS respondents (see Table 2) "agreed" or "strongly agreed" that the "post-lecture videos helped [them] improve [their] understanding of concepts in this subject", and 86% "agreed" or "strongly agreed" that the "the videos specifically targeted the areas [they were] confused about". These results suggest that the videos served their intended purpose of targeting areas where students were confused, within the FUS respondents, at least. Hence we will continue to produce these videos in future iterations of the course.

Many comments were also made about changing the role of lectures to being more interactive, such as:

I strongly suppose [sic] that the lecture should involve more practical projects...

I strongly believe the Unit of Study should transition to teaching concepts through the short, concept focused videos and leave lectures to … see[ing] the lecturer's approach to problems.

[the] lectures could be more engaging.

This is further support for the "flipped classroom" approach, in which content delivery is done at home instead of in the classroom. We are interested in moving in this direction, that is, to have short videos focusing on the technical concept, and using class time to show simple and more in-depth uses of the concept. Encouragingly, one lecture was delivered entirely by video, and a separate survey (with about 10% response rate) showed that students overwhelmingly preferred content delivery by online video, with about 70% considering it more useful than an in-person lecture.

On stream-specific assignments (DP2)

The stream-specific assignment was the second design project (DP2) given to students, in the second half of semester. When asked what "the best aspects of this unit of study" were, students responded on the USS:

Interesting problems to solve.

The assignments are giving lot of knowledges [sic] and application skills

Relevant, interesting content

… the variety of design projects is great, allows everyone to look into something relevant

… assignments are engaging.

In the FUS, 72% of respondents "agreed" or "strongly agreed" that "because the [stream-specific assignment] was specific to [their] stream, [they] were better able to understand the relevance of the content in this subject to [their] degrees" (see Table 2). Of the students that responded "agree" or "strongly agree", 82% of those "agreed" or "strongly agreed" that because the assignments were stream-specific, they "[were] more motivated to learn how to solve it". This connection suggests that presenting the assignment in a relevant context does in fact result in increased student interest and motivation, at least in the FUS population.

However, delivery of such an assignment must be carefully organized; opinions on the difficulty of the assignments was mixed, with only 38% "agreeing" or "strongly agreeing" that "the relative difficulty of [the assignments] between different streams was well balanced" (see Table 2). Several comments voiced this view, for example:

"The difficulty between streams seemed pretty uneven, which was a little frustrating. I understand that there were complications for some of the streams' tasks which definitely influenced this."

While we believe the assignments were approximately equal in difficulty, as described in the Methods section, communicating this to the students clearly could have been improved. We will attempt to make this clearer in future years. One way to do this might be to release the "fairness" guidelines used to design the assignments to the students, which was kept confidential. We are also considering tightening the relationship between different assignments by making them more uniform.

Another consideration for any assignment is the amount of guidance that instructors can give. 83% of FUS respondents "agreed" or "strongly agreed" that "[they] felt that [they] needed more guidance from teaching staff on how to approach [the design project]" (see Table 2). Too much guidance may result in students submitting seemingly good assignments despite inadequate understanding of the concepts, while too little guidance may result in students feeling helpless and unmotivated. Getting this balance right is difficult with open-ended projects; we are still considering what kinds of guidance would be best. Next year, we are considering sorting students into classes based on stream, which may allow more within-discipline discussion, but reduces the interdisciplinary nature of this course.

Conclusions

Overall, it seems that the follow-up videos were successful in addressing specific topics students were confused about, and allowing for a reusable revision resource as semester continued. While the stream-specific assignments were received with mixed opinions, our core objective of motivating students better seems to have been achieved according to our FUS sample. In future iterations of the course, we will continue to seek feedback from students to evaluate the effectiveness of this targeted approach to teaching an upper level STEM class.

Appendix

Table 2: FUS survey results

	1	2	3	4	5
The post-lecture videos helped me improve my understanding of concepts in this subject	0%	10%	7%	21%	62%
The videos specifically targeted the areas I was confused about	3%	3%	7%	41%	45%
I would prefer pre-lecture videos that give a preview of the content and concepts, rather than post-lecture follow-up videos	10%	10%	31%	10%	38%
I would prefer that the videos cover theoretical concepts rather than worked examples.	28%	28%	21%	3%	21%
DP2 challenged me to learn the content of the subject at a very high level	0%	3%	17%	28%	52%
Because DP2 was specific to my stream, I was better able to understand the relevance of content in this subject to my degree	7%	0%	21%	24%	48%
Because DP2 was specific to my discipline, I enjoyed it more and was more motivated to learn how to solve it.	3%	10%	10%	17%	59%
I felt that I needed more guidance from teaching staff on how to approach DP2.	0%	14%	3%	34%	48%
From what I know from talking to other students, the relative difficulty of DP2 between different streams was well balanced.	14%	21%	28%	14%	24%

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History and Philosophy of Engineering

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CONTEXT

Most undergraduate engineering units of study tend to focus on the development of technical skills and knowledge, coupled with the ability to apply these skills and knowledge. Engineers also need to be able to critically reflect on the nature of the work they do, using aspects of philosophical enquiry to examine and analyse the nature and impact of their work. The form of this philosophical enquiry can be very broad, and may include aspects such as; ethics, sustainability, risk, aesthetics, socio-political factors, methodology and critical thinking.

PURPOSE

To provide a learning opportunity and environment for students interested in a holistic overview of engineering; what it means to be an engineer, how engineers interact with society, how the nature of engineering has changed over time and to help create an awareness of the need for engineers to effectively use critical thinking skills and techniques when examining problems and designing engineered solutions.

APPROACH

A first-year level Unit of Study (UoS) (ENGG1000 History and Philosophy of Engineering) was developed in 2013 and has been delivered every semester since 2014. The unit is aimed at multi-disciplinary engineering students who are interested in gaining a broad overview of the history, nature, and philosophy of engineering. The UoS is delivered by a single facilitator, in a small, intimate learning environment. A traditional lecture/tutorial based teaching model is not utilised; rather every session is delivered with flexibility, driven strongly by student input. Class discussion of ideas and concepts related to the syllabus form the core basis for learning; with the direction of discussion and material covered often led by students. Students also have input into the nature and structure of assessment tasks, and corresponding assessment criteria.

RESULTS

Student feedback was obtained via formal Unit of Study Surveys (USS) and informal discussions with students, plus unsolicited emails from students. The UoS receives very favourable responses in the USS and has been awarded faculty teaching commendations. The students find it interesting, engaging and a welcomed change to their more technically focussed subjects.

CONCLUSIONS

The small class size led to a positive discussion based learning environment and students find the course interesting, primarily due to the nature of the subject matter and the learning environment. Students gain an increased awareness of various philosophical aspects of engineering, more understanding of the evolving role of engineers in society, and develop their own personal philosophy of engineering.

KEYWORDS

History, Philosophy, Engineering, Critical Thinking

Introduction and background

Most undergraduate engineering units of study tend to focus on the development of technical skills and knowledge, coupled with the ability to apply these skills and knowledge to relevant problems. However, it is also important that engineers can critically reflect on the nature, impact and significance of the work they do, using elements of philosophical enquiry and critical thinking skills; to ensure their work is aligned with the needs, expectations and requirements of society. Due to the diverse, holistic nature of engineering applications, the form of this philosophical enquiry will be broad, and may include aspects such as ethics, sustainability, risk, aesthetics, socio-political factors, methodology, critical thinking, the epistemology of engineering plus others.

This paper discusses and describes a unit of study (ENGG1000 History and Philosophy of Engineering) developed and delivered in the Faculty of Engineering and Information Technologies at the University of Sydney by the author, over the past four years. ENGG1000 is a first-year level free elective aimed at engineering students who are interested in gaining a broad overview of the history, nature, and philosophy of engineering. Enrolment levels are approximately 20 per semester, with most students being in their final year of undergraduate study and from all engineering disciplines within the Faculty. Students mostly have a genuine interest in the subject matter and engage with the material, but there are also always a few that take the course to enable full enrolment load or for other various reasons.

The aim of the paper is to introduce the unit of study and provide background/context and reasoning for the importance of the subject matter, in the context of engineering curriculum. It is hypothesised that students achieve positive pedagogical outcomes, such as improved critical thinking skills, greater levels of engaged enquiry and an awareness of the role engineers play in shaping society.

Philosophy of engineering

Philosophy of engineering is a recent area of study that is similar in many ways to philosophy of science, but much less mature in its development. Applying philosophical principles to engineering is not new and engineers often do so without realising, but creating a greater awareness of philosophical methodology in engineering students through formal study is less common. There is much scope for philosophy to help inform the practice of engineering, and for engineering to inform and raise philosophical questions. Gaining greater understanding of philosophical concepts and techniques can be of advantage to engineers dealing with complex problems; through the methods of conceptual clarification, critical thinking and clear argument (McCarthy, 2007).

Merging philosophy and engineering together can be difficult, primarily when analysing the conception of knowledge, with knowledge generated by engineering normally differing from knowledge generated by philosophical reflection. Large scale engineering projects contain a vast amount of knowledge, generated by many teams and the resultant knowledge is held by organisations, rather than by individuals (McCarthy, 2007). Much of the knowledge generated by engineering projects can also not be verified by scientific theories, due to the imprecise nature of many engineering activities. It is therefore of value to explore and analyse the methodology of engineering, in order to gain a greater philosophical understanding of the nature of engineering (Bulleit, Schmidt, Alvi, Nelson, & Rodriguez-Nikl, 2015).

Engaged and enquiring minds

A general move towards online, flipped and blended learning strategies in engineering education has led to students' requiring a greater self-motivation to learn and manage their own learning activities. First year students especially find this more difficult as their learning prior to University entrance is typically more teacher oriented. Successful latter year engineering students have generally developed more effective personal learning strategies, and perhaps also a stronger ‘enquiring’ mind-set.

Engineering students’ exhibiting greater enquiring mind tendencies are typically more motivated to study, seek information through research (most often online) and develop a greater understanding of subject matter and the context in which is relates to or is applied, and generally adopt a ‘deep’ learning approach. From the author’s experience as an engineering educator, a minority of engineering students exhibit strong ‘enquiring mind’ tendencies.

In the current global environment, for a graduate engineer to be of increased value and use to an organisation, the possession of an enquiring mind is a valuable attribute, and should lead to better, more thorough and original engineering. Engineers that exhibit attributes of an enquiring mind should be more creative, innovative and thorough in engineering practice.

> *"The enquiring mind of engineers - 'how can I do it better, faster, safer' - has enriched human life on so many levels.”* (Alexander, 2016)

Developing strong student engagement is a common aim of educators, with an expectation that students who are engaged in their learning will comprehend material faster and with ‘deeper’ understanding. Engaged students should also develop stronger foundations for life-long learning, a trait that is especially relevant to engineering students expected to undertake a life time of ongoing professional development.

Increased student engagement in learning should lead to a faster development of attributes related to an enquiring mind, as the students move towards deeper learning and understanding of the subject matter.

Another positive method to help develop a stronger sense of ownership and engagement with students is to actively involve them in the formation of assessment activities and corresponding assessment criteria (within reason and with limitations).

Most engineering courses delivered at University level do not actively or explicitly incorporate elements of philosophical enquiry, but rather are focused on the development of technical knowledge, skills and understanding. Encouraging students to actively analyse their knowledge and understanding, with questions such as; how they obtain knowledge? where did it come from? is it true? how do I know it’s true? can I improve/expand on this knowledge? can I apply it to different contexts? etc. helps foster the development of an enquiring mind, aiding these students to go beyond the ‘average’ engineering student’s level of knowledge and understanding.

Critical thinking skills

Engineering students often lack critical thinking skills, or the ability to think critically *about* engineering, not just *within* engineering (Claris & Riley, 2012). Critical thinking skills and techniques are of vital importance for successful engineers, the ability to critically analyse information, processes and knowledge leads to more informed decision making, and corresponding beneficial outcomes to society.

The development of strong critical thinking skills in engineering students should also lead to higher levels of engagement and philosophical enquiry.

Epistemology of engineering

Epistemology of engineering has changed over time, from ancient observers and experimenters, through the master and apprentice model and eventually to modern formal engineering education based on scientific knowledge and methods. Different students learn in differing ways, and creating an awareness of one’s own learning strengths and weaknesses through reflective learning is an important skill for engineering students to obtain, leading to more effective continual professional development.

A current challenge for engineering educators is to create a knowledgeable generation of engineers, who have the skills and knowledge beyond those presented in traditional engineering curriculum (Hamzah, Ismail, & Isa, 2012).

Flexible, intimate learning environment

Smaller, more personal learning environments should have a positive impact on student engagement levels, provided the subject matter is interesting, relevant and engaging. Active contribution to discussions by students gives them a greater sense of involvement, and coupled with the ability to guide the discussion's direction, an increased sense of personal ownership of their own learning. When used in this way successfully, these class-wide discussions can lead to greater student engagement and help in the formation of philosophical enquiry.

Engineers and society

Interaction between human society and engineers has helped develop and guide the advancement of engineering technology and humans; with society posing problems for engineers to solve, and engineers developing new technology that changed the course of human history, helping shape the world we live in now. This interaction is vitally important for society to continue to develop in a sustained manner.

Historical changes in the nature of engineering

Many engineering students have an interest in the history of engineering and there is an enormous amount of information that exists. By examining the nature of engineering 'breakthroughs' over time and the subsequent impact on society, students gain an improved understanding of the potential impacts of their own engineering work.

The changing perception of society's views of engineers is also of interest, as throughout history the 'place' of engineers in society has varied. As we head towards an era of increased automation, the engineer is yet again placed in the situation of potentially creating large impacts on society, both positive and negative. Examining historical engineering processes, events and technologies aids engineering students to appreciate the multiplicity of causes and effects that are involved in the discipline, plus encourages students to ask how and why something did or did not happen, and to develop their own personal perspectives on 'how and why' (Dias, 2014).

The world is on the cusp of another great industrial revolution, the age of oil and coal is coming to an end, and increased use of automation will likely change the very nature of work for a large proportion of society, and have potentially huge impacts on the world. Engineers are very much responsible for these changes and need to be aware of the ethical and social implications of decisions they make, and impacts of engineering they perform.

Implementation

A traditional lecture/tutorial based teaching model is not utilised in this unit; rather every session is delivered with flexibility, driven strongly by student input. Class discussion of ideas and concepts related to the syllabus form the core basis for learning activities; with the direction of discussion often led by students. Students also have input into the nature and structure of assessment tasks, and corresponding assessment criteria.

Unit content/syllabus

The unit is delivered every semester and the general course structure is listed below:

1. Introduction, what is engineering?
2. History of engineering 1 (prehistory – romans)

3. Methodology and philosophy of engineering
4. Engineering and society
5. History of engineering 2 (medieval – industrial revolution)
6. Epistemology of engineering and professional development
7. History of engineering 3 (1880-1950)
8. Socio-politics of engineering and technology
9. History of engineering 4 (1950-present)
10. Critical thinking skills
11. Engineering and society, the future?

This general structure has been developed based on student feedback and class interaction; students always have strong interest in more discussion of the historical aspects of engineering, and those sessions can be hard to keep to schedule. A strong focus has been kept on course components that are related to the development of skills relevant to critical thinking and engaged philosophical enquiry; skills that should lead to an increased development of an enquiring mind.

The exact weekly content does vary somewhat, based on student interest and the extent, content and direction of classroom discussion. Topics of discussion that require further investigation are noted and taken to online forums for further investigation and discussion.

Assessment activities

Assessment tasks

There are currently six assessable tasks/activities in the unit:

1. Oral presentation
2. Written report
3. Online multimedia blog
4. Quiz
5. Active class participation
6. Active online class participation

The oral presentation involves short presentations to the class of a significant engineering event or breakthrough, and discussion of the impact of the event/breakthrough on society.

The written report task varies based on students' ideas and proposals, generally there is a focus on technological breakthroughs, but some students explore the more philosophical aspects of the unit material.

The online multimedia task is well received by most students, as it allows them to utilise a large variety of sources of information and material, generally focusing on the evolution of a historical engineering technology/product and the subsequent impact on society. Some students have got very engaged in this activity and created over 40 posts during eight weeks. Other students engage with individual blogs by adding comments to posts.

The quiz is an in class short answer mini exam that assesses the students' understanding of the unit material and their ability to demonstrate and use philosophical concepts introduced in the unit.

The last component of assessment is class participation, both physically in class and also in an online learning environment (Blackboard LMS).

Student contribution to assessment task details/criteria

A popular feature of the unit is the ability of students to have active involvement in the development of the actual assessment tasks and grading criteria (within reason). Students are free to suggest the nature of topics for the report and blog, and as a class wide group determine many aspects of the grading criteria (within reason).

Student reception and feedback

USS Results

Over the seven instances that the unit has been delivered, the overall student satisfaction (as obtained through the Unit of Study Survey process has averaged 4.4/5.0). The unit has received multiple Faculty commendations.

In answer to the question "What have been the best aspects of this unit of study?", (via the formal Unit of Study Survey process) students' comments included:

> *"Engagement in classes. While tangents that occur in class can lead to us falling behind schedule, they are extremely interesting and really lead to challenging my perceptions about what it means to be an engineer - and what my responsibilities will be, especially when relating history and philosophy to major engineering projects throughout the past."*

> *"This unit of study is one of the best ones that I have come across. The quality of teaching was spot on. This unit should be added as one of the core units. Everything about this unit was excellent and interesting."*

> *"This was a very unique uos. Rod's units have always been different in a good way. This class was more of a conversation between everyone rather than Rod teaching. This was very enjoyable, and I wish we could have had more classes."*

> *"The most interesting unit I have had this semester. The overall purpose of the unit was clear and has changed the way I think about engineering within society."*

> *"Overall, the course itself was enjoyable and very fascinating. Being able to understand the past and present of engineering is such a key aspect to the success of future engineers."*

> *"Open forum discussion was a great change from the normal unit. It has helped me develop skills that aren't really taught by any other subject"*

> *"It's a very interesting course and encourages me to use my own research skills to supplement what is learnt in class. It's very student-driven, and no maths, which is a nice change... The assessment tasks are also very enjoyable, and I like that they are so self-driven and you can do them on pretty much whatever you want. The format and small class sizes are also really good."*

> *"I really enjoyed it. I didn't think I would, but I think it's going to help me be a better engineer."*

Students have also occasionally provided unsolicited feedback via email, such as:

> *"…would like to say I miss History and Philosophy a lot. It was hands down the best subject I've done in my time at Sydney University."*

In semester 2 2017, one student has returned from the previous semester to attend many of the sessions out of their own interest.

This year, two students that completed the unit have proposed and undertaken final year thesis projects with the author, related to engineering ethics. They attributed their interest in this field of research to having previously completed the unit of study.

Informal discussion sessions with the students indicate that the students find the course interesting and enjoyable, very different to their regular courses, and engaging - through both the nature of the subject matter and delivery of content. Students appreciate the flexibility in the course structure and the positive reception/incorporation of their ideas/thoughts into the course content and direction.

Student dissatisfaction does occur but is minimal and normally relates to face to face teaching hours being insufficient (majority of class does not want to increase the hours) and the subject of assessment tasks being too similar. Students were recently given greater freedom to generate their own assessment tasks (within reason) and a small number do take this opportunity to negotiate different tasks.

Discussion

Encouraging the development of an enquiring mind aids students' engagement and levels of self-efficacy, by enabling them to obtain a deeper level of learning and understanding. (Patterson, Campbell, Busch-Vishniac, & Guillaume, 2011) Students are also more likely to gain a positive attitude towards learning and increased self-confidence (Riegle-Crumb et al., 2015) and are expected to have developed the basis for fundamental enquiry based competencies, which should aid them in future professional careers and improve their own agency and responsibility (Terkowsky, Haertel, & Bielski, 2014).

Informing students about concepts related to the epistemology of engineering helps them critically reflect on their own learning style, and to identify their personal strengths and weaknesses, which aids their continual ongoing professional development.

Discussing the historical development of engineering as a profession helps encourage development of an enquiring mind, as students generally gain interest in historical engineering events and undertake independent research.

Much of the unit's assessment activities revolve around the interaction between engineers and society, and how engineers have a very large and crucial role in the development and progression of society. Reinforcing this understanding in engineering students will help make them a more valuable member of society, and help align them with expectations of society.

Small class sizes foster an increased sense of involvement in students, normally leading to improved student engagement. Class wide discussions have proven very effective in generating student interest, and the multidisciplinary nature of the student cohort leads to an improved understanding of the more holistic and diverse nature of engineering. Active learning activities like effective class debate and discussion leads to more engaged students with stronger critical thinking skills (Hamouda & Tarlochan, 2015).

The difference between online and in class engagement is evident; students that may have difficulties speaking in class are often more active in the online environment, and the use of online discussion enables students to provide references and links etc. Students are actively encouraged early on to initiate their own discussion threads, with varying levels of success; some students will only ever reply to existing threads, whilst others engage an enquiring mind-set and actively seek new topics and points of interest to discuss.

The unit is not without issues, predominantly that by encouraging active class wide student led discussion it can be difficult to keep the unit on schedule; often active and lively discussions need to be stopped and taken online due to in-class time constraints, which often leads to students then becoming dis-engaged with the topic of discussion.

The unit tends to start with a more guided form of enquiry, with the unit facilitator posing questions and normally initiating/leading discussions earlier in the semester, with the aim of informing students about concepts and processes involved in philosophical enquiry. Students are then provided with less guidance and encouraged to form a more open style of enquiry, with the aim of improving their own self-led enquiry skills.

Conclusion

An engaged, philosophically enquiring mind

This paper provides a background and overview of a new unit of study related to the study of history and philosophy of engineering, outlined the general aims and unit structure, plus the expected and observed learning outcomes.

Small class sizes led to a positive discussion based learning environment and students find the course interesting and engaging, primarily due to the nature of the subject matter and the learning environment.

Students' completing the unit gain; a greater awareness of the role of engineers in society, improved skills and ability in philosophical enquiry, stronger critical thinking skills and greater development of an enquiring mind-set. These outcomes will enable students to become better engineers of more value to society, with the ability to greater inform themselves of impacts and implications of engineering projects/technologies, and to apply techniques of philosophical enquiry to make better decisions and create better products for the benefit of humankind. Elements of the unit could be applied to many other engineering units of study, specifically areas such as engaged enquiry and critical thinking and

It is the author's intention to undertake a scholarly longitudinal investigation of the learning outcomes related to this unit, in particular the concept of the encouragement and development of an enquiring mind-set in students, and whether it can lead to the creation of 'better' engineers for society.

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eLearning initiatives - can their effectiveness really be measured?

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SESSION
C1: Integration of theory and practice in the learning and teaching process

CONTEXT
As students' preferred ways of working change over time, so too must the ways in which research skills are integrated in the curriculum. Subject librarians collaborated with academic staff to improve the integration of research skills into a core first year engineering course by changing the mode of delivery from face-to-face only, to a blended model. The change in research skills delivery was concurrent with a move from summative to formative assessment methods within the course and a change in institutional learning management system (LMS). These changes allowed subject librarians to deliver content in a sustainable way that ensured a positive student experience given the predicted growth in enrolments in engineering.

PURPOSE
The end-goal for this work was to improve student outcomes in independent research, referencing, and academic writing, in a more sustainable and accessible way.

APPROACH
An eLearning Research Skills course was created, which was linked to the first course assignment using constructive alignment (Biggs, Tang, & Society for Research into Higher Education, 2011) and was integrated into the LMS. The eLearning Research Skills course addressed student needs and incorporated learning outcomes which were concept-based and practical, rather than skills based. Optional face-to-face support was also available via targeted assignment-specific drop-in sessions. User research and needs' analyses were carried out through pre- and post-implementation staff interviews (assignment markers, course coordinator) as well as student focus groups, interviews and an in-lecture survey.

RESULTS
Staff interviews and student feedback (via the self-evaluation checklist) indicated that the move from face to face to blended delivery maintained student performance. Advantages were noted in sustainability of staff resources and student access at "point of need". The eLearning Research Skills course also provides a good foundation for future studies.

CONCLUSIONS
Measuring the effectiveness of programme-specific eLearning initiatives was challenging. Further research is required to explore methodologies for evaluating the effectiveness of a blended learning approach.

KEYWORDS
Blended learning, eLearning, research skills, curriculum integration

Introduction

The ENGGGEN140 course is a first year core programme course in the Faculty of Engineering with an intake of more than 850 students in semester one 2016. The number of students enrolled in the course increases every year and it is expected that enrolments will reach 1000+ by 2020. Thus the engineering subject librarians face significant challenges in terms of sustainability of the face-to-face delivery of research skills. Research skills include identifying appropriate information sources; searching for information; evaluating information; writing and referencing. Research skills are important for developing student interest in research programmes (Saylor & Kukreti, 2016) and for the development of desirable graduate attributes.

A change in the university LMS in 2016 to Canvas provided the opportunity for subject librarians to work with academic staff to improve the delivery of research skills content; from face-to-face only, to a blended model. Canvas is an open-source LMS developed by Instructure (Whitmer & Daley, 2008). The blended model included an eLearning Research Skills course and drop in sessions allowing students to have a face-to-face discussion on their assignment and ask questions of subject librarians.

The eLearning Research Skills project was initiated in May 2015. The eLearning Research Skills course was launched in March 2016 and was embedded into the ENGGGEN140 course in Canvas.

Aims

Initial interviews with the course coordinator and assignment markers suggested that students were poor to middling at research and referencing. Academic writing and referencing techniques were not covered well in the existing face-to-face course. The purpose of the eLearning Research Skills course was to improve student outcomes in the areas of research, referencing and academic writing, attributes reflected in several of the capabilities of the Graduate Profile (The University of Auckland, 2017), and to deliver coursework in a more sustainable and accessible way.

Methodology

User Input

A variety of methods were used to identify the key issues: interviews were conducted with staff involved with the course before the introduction of the e-Learning initiative; students who had completed the course previously were surveyed and participated in focus groups. Questions asked on Piazza about academic and information literacy were analysed by type. Piazza is an online platform where students can ask questions about the course content and other students, teachers and other staff associated with the course provide the answers in real-time (Sankar, 2009). Written workshop evaluations submitted in 2015 were analysed and an in-lecture survey was conducted in 2015, before the eLearning Research Skills course design was initiated. Findings from the in-lecture survey showed that students found the research skills taught by subject librarians beneficial to their assignment completion. Furthermore, students indicated that the blended model was their preferred delivery mode for this type of content.

The ability to identify and distinguish between appropriate information sources, referencing and citing and writing appropriately for engineering were all identified as areas where students needed support. Previous research conducted on similar topics has also identified the same key issues faced by engineering undergraduate students (Ali, Abu-Hassan, & Daud, 2009; Blicblau, Bruwer, & Dini, 2016; Wertz, Purzer, Fosmire, & Cardella, 2013).

Effectiveness of the eLearning Research Skills course was evaluated after implementation. Staff were interviewed about student performance and students provided feedback using an optional online feedback form.

Design Approach

A student-centred design approach was adopted. Elements of constructive alignment (Biggs et al., 2011) were used to ensure that learning outcomes, learning and teaching activities, and assessment were linked. In order to support diverse learning styles (Mestre, 2006) a blended model with optional face-to-face support was delivered via targeted assignment-specific drop-in sessions.

The design principles of the eLearning Research Skills course were derived from the three broad theoretical perspectives: associationist (learning as activity), cognitive (learning as achieving understanding) and situative (learning as social practice) (Greeno, Collins, & Resnick, 1996; Mayes & De Freitas, 2004). For example, the eLearning Research Skills course included sources of information with repeated patterns, showing differences between them, followed by activities. Each module of the eLearning Research Skills course had self-tests with immediate feedback provided. A self-evaluation checklist was provided for students enabling them to self-assess their performance and learning.

Constructivist perspective where students build knowledge and make meaning (Biggs et al., 2011) underpinned the design. The eLearning Research Skills course was aligned with the first assignment and integrated into Canvas giving it clear meaning and purpose. By using the skills learnt from the eLearning Research Skills course students were able to complete their first assignment and reinforce capabilities in research and writing that would support them through subsequent coursework requirements in their degree.

Assessment

Assessment of skills acquisition by students was the most challenging part in designing the eLearning Research Skills course. Due to the large class size, assessment was based on multiple choice quizzes. Multiple choice quizzes are not an ideal form of assessment as they can inadvertently encourage surface learning (Biggs et al., 2011). However it is possible to avoid surface learning while still using these quizzes by making questions scenario based (Hulse, Han, Melnichenko, & Brookes, 2011). See Appendix 1 for an example scenario question.

Formative assessment self-tests were built into the content of the eLearning Research Skills course, allowing students to test their knowledge throughout, with immediate feedback provided. A self-evaluation checklist was included at the end of the eLearning Research Skills course with links to further help, advice and resources if students were still unsure of the material.

However, because students were allowed unlimited attempts to complete the multiple choice quizzes, it was difficult to gauge the learning progress of students from the eLearning Research Skills course alone.

Results and Discussion

Staff interviews and student feedback indicated that the move from face-to-face to blended delivery maintained student performance. By using the final self-evaluation checklist at the end of the eLearning Research Skills course, students self-assessed their performance and learning, noting improvements in finding resources, writing and retaining information. However, comments from assignment markers and the course coordinator at the end of semester were more revealing, showing that although improved, issues in writing and referencing still persisted. Therefore, there is still room for improvement in the writing and referencing modules of the eLearning Research Skills course.

Students provided feedback via an optional online feedback form. Students commented that they liked the self-tests and videos used throughout the eLearning Research Skills course. Students also commented that the eLearning Research Skills course was too long and that the videos could be improved with the addition of background music; further areas for development.

Some improvements have been noticed in the sustainability of delivery and accessibility of the content. Content is able to be delivered more sustainably in the context of staff hours to 850+ students by using Canvas. The previous mode of content delivery used face-to-face workshops and library tours and took approximately 106 staff hours each semester to deliver. Delivering the content via Canvas takes one staff member approximately five hours to load the content and set up the multi choice quizzes.

Sustainability in delivery of the eLearning Research Skills course was improved by moving to a blended mode of delivery. However, a significant investment of time was still required to develop the e-Learning Research Skills course. Thus, library staff time requirements have moved from delivery to development, with a concomitant improvement in resource quality.

Accessibility of content has been greatly improved for students. The previous mode of content delivery meant that students could only attend at set times and made no allowances for timetable clashes, unavailability or forgetfulness on the part of the student. By making the content available online 24/7, students can access it when and wherever they like, at point of need.

The authors have found that an eLearning approach allows for consistency of content delivery and for pedagogy to be improved. The e-Learning Research skills course provides a good foundation for student research and writing skills and supports students through subsequent course work requirements in their degree.

Conclusion and Recommendations

Investigating ways to assess and measure the effectiveness of eLearning is a common research theme in this area. Findings of previous studies are the same or similar; there are distinct benefits to learners who participate in eLearning with those benefits furthered for learners participating in blended learning (Liaw, 2008; Shittu, Olufunmilola, & Osunlade, 2016; Wong & Ng, 2016).

Evaluation methodologies that could be used to evaluate the effectiveness of the eLearning Research Skills could be adapted from those used in a real-life engineering case study of an online library tutorial (Hulse et al., 2011). Methodologies included direct observation, online feedback, test results, and a qualitative questionnaire, ideally these would be applied with before-and-after course assessment. The assessment of effectiveness of the eLearning Research Skills course remains problematic without within-cohort measures of improvement. Further research is required to explore methodologies to evaluate the effectiveness of the blended learning approach.

Appendix 1 - Example scenario question

You have just received your assignment topic and need to start looking for information. This is difficult as you don’t fully understand the topic yet. You need to get a good overview of the topic so you try the following sources. Which one is the best choice in this situation?

A. A newspaper

Incorrect. While a newspaper is good for later in your assignment it is not a good starting point for a basic overview.

B. A blog

Incorrect. While a blog may contain useful information about your topic, it is not a good starting point for a basic overview.

C. An encyclopaedia

Correct. An encyclopaedia entry is both peer reviewed and provides an overview of your topic, allowing you to find out where your assignment question fits in to the wider context. Use encyclopaedias to discover key terms, dates, people and themes relating to your topic, prior to searching for more specific information.

D. A journal article

Incorrect. Journal articles can be very specific and concentrate on narrow subtopics within the broader subject area so are not a good starting point for a basic overview.

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The Self-Directed Learning Readiness Survey as a Predictor of Success in a Problem-Based Learning Environment

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Charles Sturt University (CSU) launched a new engineering degree in 2016, with a strong focus on self-directed and self-motivated learning. Admission to the programme was based on ATAR, a secondary application form, and a candidate interview. Staff reflections at the conclusion of the first year showed that these three metrics alone did not sufficiently identify candidates able to complete topics, i.e. engineering content learning and assessment modules, at a sufficient pace to progress on to the latter stages of the course. In an effort to improve the recruitment and candidate evaluation process the staff decided to trial a survey measuring student perceptions of their readiness to partake in a self-directed learning environment.

PURPOSE The purpose of this study is to see whether students' scores on the Self-Directed Learning Readiness Scale (Guglielmino, 1977), or the Learning Preference Assessment (Guglielmino & Guglielmino, 1991), are predictive of eventual academic success specific to topic completion.

APPROACH The Self-Directed Learning Readiness Survey was administered on a volunteer basis amongst the student cohort in the first week of the first semester; the outcomes of the survey were compared to topic completion data and a student reflective prompt on the experience.

RESULTS Neither the quantitative or qualitative data showed any conclusive evidence connecting student perceptions of self-directed learning and topic completion. When controlling for sex, cohort, or school-leaver versus mature-aged, no strong correlations emerged between SDLRS scores and the number of topics of completed. This is potentially a result of a small sample size, self-selection bias of participants, or lack of longitudinal analysis beyond the first 6 months.

CONCLUSIONS With neither student SLDRS scores, or written perceptions of self-directed learning, showing anything conclusive explaining topic completion in the CSU programme, other methods of administration or tools will need to implemented in the future to better target the desired outcomes.

KEYWORDS Self-Directed Learning, Problem-Based Learning, Topic Completion

CONTEXT

Charles Sturt University launched its engineering programme in 2016 on the foundation of a self-directed learning paradigm coupled with a series of engineering challenges and industry placements. The admissions procedure involves potential candidates submitting their transcripts, ATAR, and take part in an interview with CSU staff. The results of this process have shown a wide range in academic performance by admitted students, made particularly visible in their rates of topic completion (Sevilla, Senevirathna, Li & Lindsay, 2016). As a result of the breadth of academic performance between the first and second cohorts, additional predictive mechanisms have been trialled.

PURPOSE

The purpose of this study was to analyse if student perceptions of self-directed learning readiness translated into academic performance, particularly in regards to topic completion. Self-directed learning as an educational phenomenon has many different definitions and interpretations (Chi, 2009). For this study, we used Gureckis and Markant's definition of self-directed learning which states "allowing learners to make decisions about the information they want to experience" (Gureckis & Markant, 2012, p. 465). This distinction has implications for both what is learned and what is learnable. The central premise of the self-directed paradigm is agency in choice of content, along with the ability to situate oneself within their existing knowledge schema, as opposed to passive learning in which the choice of information selected is limited and directed by the instructor (Rehder & Hoffman, 2005). The combination of agency of choice of learning material along with objective metrics to assess one's progress have both been shown to be powerful tools in supporting students' efficacy beliefs (Schunk & Pajares, 2002) and act as a theoretical backbone for the CSU programme.

CSU's engineering programme was founded in 2016 under a self-directed learning paradigm in which students have access to a wide array of pre-requisite-free content from Day 1 of the programme and can progress through additional content at a pace of their choosing. This method of progression through an engineering degree is unique in that once students begin the degree, they are required to guide their own pathway and rate of topic completion as there are only two major milestones at 18 months, and again after four years of placement.

Given the self-directed nature of the programme, the Self-Directed Learning Readiness Scale (SDLRS) was administered to both the first and second cohorts to assess if there exists a correlation between their SDLRS scores and their topic completion performance. The SDLRS is a 58-item survey instrument that was developed by Guglielmino (1977) and modified later to the Learning Preference Assessment (Guglielmino & Guglielmino, 1991) in an attempt to remove respondent biases associated with the previous instrument name. Given the self-directed nature of the CSU programme, the results of the SDLRS were used to see if any trends emerged that could explain student performance towards topic completion in the programme.

APPROACH

In addition to the SDLSR survey data, we collected qualitative data obtained from student responses to a reflection prompt. Students completed written reflections, where they reflected on their a) understanding of self-directed learning and b) identified areas for improvement in the following weeks of the semester. The reflections on self-directed learning were completed in participants' first-year, first-semester of the programme in the context of a design and project-based course.

Students selected to use the self-directed learning themed reflection from several options, which focused on other themes such as teamwork, service learning and ethics. At the time of this study, six students who participated in the SDLSR survey also utilised the self-directed learning reflection prompt.

To utilise students' written reflections, we extracted responses regarding their perceptions of self-directed learning. In this paper, we qualitatively analysed the response data from the first prompt: *"What does self-directed learning mean to you?"*

The study collected qualitative data from six of the 15 total participants, where the written reflections were best used to get further insights into students' perspectives on self-directed learning at this stage in their engineering studies.

RESULTS

Quantitative: SDLRS and Topic Completion

In total, 14 students completed the SDLRS survey which reports scores of 58-201 as below average, 202-226 as average, and 227-290 as above average with a mean of 214. Table 1 illustrates the results of the survey and the corresponding number of topics completed by each participant. The classifications from left to right designate male (M) or female (F), first (1) or second cohort (2), school-leaver (S) or mature-aged (M), and which student within this category (a, b, c, d, e).

Table 1: SDLRS vs. Topic Completion

Participant	Percentile	SDLRS Score	Topics at 6 Months
M1Sa	18%	193	7
M2Sa	66%	227	189
M2Ma	92%	254	125
F1Sa	60%	223	97
M2Sb	83%	241	112
F1Sb	63%	225	62
M2Sc	74%	233	70
F2Sa	76%	236	81
M1Sb	8%	181	107
M2Sd	69%	230	68
M1Ma	92%	253	15
M1Mb	76%	235	69
M2Se	69%	230	121
M2Mb	33%	205	122

In addition to the raw data shown in Table 1, a graphical representation illustrates these results in Figure 1.

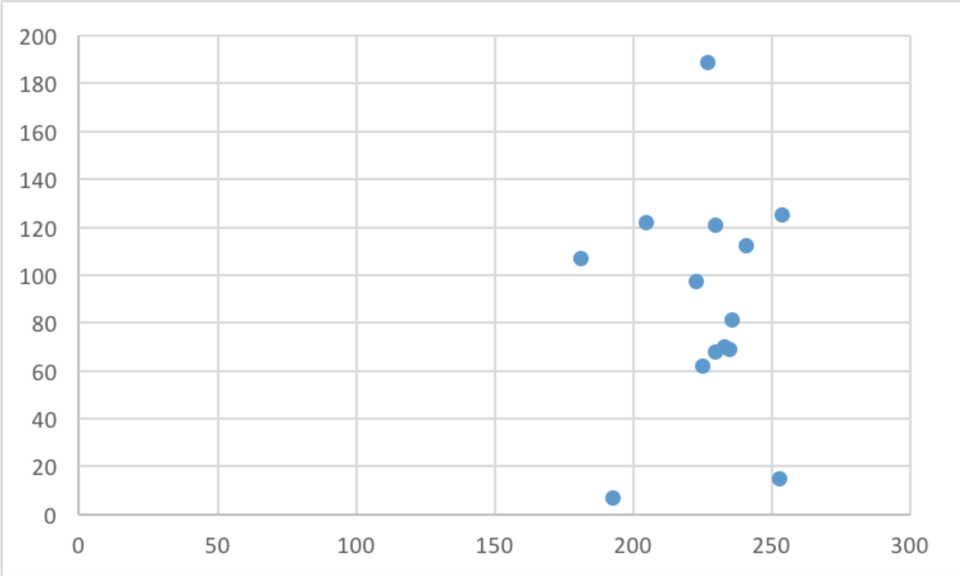

Figure 1: SDLRS Score vs. Topic Completion Across Cohorts

As shown in Figure 1, the statistical analysis was inconclusive. When controlling for sex, cohort, or school-leaver versus mature-aged, no strong correlations emerged between SDLRS scores and the number of topics of completed. This is potentially a result of a small sample size, self-selection bias of participants, or lack of longitudinal analysis beyond the first 6 months. Given that CSU's first major topic completion milestone occurs at 18 months into the programme, this may be a better measure of the effects of students' perceptions of their readiness to embark on a self-directed learning curriculum.

Qualitative: Student Perspectives on Self-Directed Learning

We utilised student perspectives on SDL, based on their qualitative feedback, to provide context for the SDLR survey responses. We extracted responses from participants that completed both the SDLR survey and SDL reflection, *"What does self-directed learning mean to you?"* The qualitative findings support the context of SDL in this study, and provide possible comparisons with the existing definition, and models of SDL.

Participants reflected on the meaning and application of self-directed learning in various ways. The student responses suggest qualitatively different perceptions of self-directed learning, and how it applies to their own studies. When asked about the meaning of self-directed learning students responded:

> P2: "Self-directed learning involves several aspects including, self-motivation and self-discipline. When a balanced is attained productive self-directed learning can be achieved."

> P5: "Self-directed learning is the process in which an individual has the responsibility to identify their learning needs and to act in a manner that meets all learning needs. This means that the certain person must be willing to self-learn content, although help may be provided upon requesting, and ensure that they have learnt what's required."

The responses from participants P2 and P5 display an awareness of self-directed learning as a framework to utlise self-motivation, and discipline, in order to identify and learn content. These participants also linked self-directed learning to an interest in 1) learning, 2) possessing an interest in the material, or 3) acknowledging the material is applicable to their current work, e.g. design projects. Participant P2, goes on to describe that "I am more dirven to learn the subject content of topics when I am interestedin the topic, or when the topic is relevant to the design challegne that I am working on [sic]." Participant P5 forecasts that the motivation to “self-learn content” is due to needing this skill in the workforce, e.g. “…that out in the workforce, no one will be next [to] an engineer telling them how to do their job.”

Other participants responded with their perspectives of self-directed learning:

> P1 “ Self-directed learning involves an individual being able to learn without the assistance of an academic or peer. Work is completed entirely by the individual without any help.”
>
> P6: “Self-directed learning means that an individual is able to learn, reflect and improve regarding events constantly without anybody explicitly informing the individual the result. Individual is aware of the environment and able to process what is required that are not yet acquired, then proceed to leaning the information with credible sources, thus requirement could be met in a professional manner.”

These types of responses focus on learning from a more independent approach. Self-directed learning is also without the assistance of peers or academics, or someone explicitly directing the student. Participant P6 expanded on the role of the individual in the learning experience, where the individual also needs to acknowledge what they know, do not know, and how to acquire the relevant information for learning.

We point out that the participants are first-year students (first-year technically within the identified curriculum in this study), and acknowledge that inexperienced students are more challenged with minimal guidance. Participant one (P1) highlights the possible difficulty in understanding how self-directed learning can be utilising more than the individual component related to learning, i.e. support from instructors and peers.

Participants P3 and P4 chose to reflection on how they could improve their approach to self-directed learning, including how to seek better resources or document their learning process. In these instances, the respondents placed responsibility on the individual on the way information is acquired and how it it can be used to help them progress in their degree.

> P3 “My goal [for self-directed learning] is to seek better resources when researching a topic.”
>
> P4: “The element of self-directed learning that I wish to improve upon is the documentation of learning, an aspect that I perceive as integral within the [course] curriculum.”

The definitions and perspectives varied from participant to participant, however statements made by participants expose some elements related to the learner making decisions about what they chose to experience, which aligns with the Gurecki & Markant (2012) definition of self-directed learning.

CONCLUSIONS

Based on the data collected for this study, the SDLRS cannot be used as a sole predictor of academic success in a primarily self-directed learning environment nor students’ perspective on the meaning of self-directed learning. While this study is greatly limited by sample size, larger participation in the future would likely provide greater clarity as to the value of the SLDRS as a predictor of performance in a self-directed learning programme. What is clear at this junction is that with a small sample size, the data is susceptible to strong outliers, and further, with the data being collected in the first 6 months of the programme, that various types of behavioural changes pertinent to topic completion soon emerged prior to the 18 month-240 topic deadline were not represented.

Moving forward it will be important to trial the methods outlined in this paper on a wider sampling of students across cohorts and triangulate this data with further performance metrics across the active cohorts in the programme. Lastly, beyond student perceptions of ability, it will also be valuable to explore various methods of scaffolding students to adjust to the realities of a self-directed paradigm so that they can be successful within the context of the programme and beyond.

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Data-Mining work experience reports

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SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

As part of their work experience students are required to complete a 6000 word report. In addition to description of the work performed students are asked to describe three skill areas (from a list of seven) which have been most developed, to comment on the professional context of their work, to reflect on their studies and to make suggestions for changes to the degree program.

PURPOSE

The aims of this study were to mine the wealth of information which students record in their final year work experience reports, to collate the data and use it to make improvements to the educational experience of students, to make more effective integration of the practical experience into the degree, and provide the school with enhanced industry contacts.

APPROACH

407 student reports covering a period of 5 years were reviewed both qualitatively and using algorithmic text mining. Available pdf files were converted to text files and the text scanned to determine frequently used words and phrases. Statistics of the areas where students were engaged, the skills most exercised and differences between local and overseas experiences were obtained. Particular attention was given to identifying areas where students were poorly prepared.

RESULTS

The free form of the student reports presented challenges in extracting consistent and meaningful data. Nevertheless, statistics were developed showing which sectors of civil engineering were employing most students, and of the skills most required. It was noted that within Australia communication skills were seen as very important, whereas for students doing work experience overseas design was the main skill used and communication the least. For all students professional conduct and teamwork skills were significantly enhanced.

CONCLUSIONS

It is recommended that a revised web based report be developed to enable more thorough and reliable statistics to be obtained, that greater efforts be made to coordinate student and employer expectations and to enhance student workplace readiness. Skill areas where students reported the most challenges were in information seeking, teamwork skills and professional communication, and it is recommended that these be better addressed in the preparatory programs.

KEYWORDS

Work experience, Generic skills, Work readiness

Introduction

Work experience is integral to all engineering programs in Australia, and it is considered important and valuable by all stakeholders: students, industry and academics (King, 2008). Currently Engineers Australia requires industrial training as part of any accredited engineering degree, with this usually taking the form of 12 weeks' full-time work. Although the benefits are widely agreed upon there appears to have been little academic study of the benefits of work experience in engineering within Australasia apart from a report on a newly developed program in computer engineering (Pauling and Komisarczuk, 2006). There is anecdotal information that suggests students are finding it harder to acquire quality experiences, employers report being overwhelmed by applications, and increasingly work experience is being unpaid. As noted by King (2008) the challenges involved in finding work experience lead to a small, but growing number of students not completing their work experience until after their academic studies are finished, resulting in delays in graduation and also an undesirable lack of integration of the experience with their studies. At the same time the government is introducing more obligations on universities to ensure the quality of work experience, particularly where this experience is integrated with the degree. There is a general movement in higher education towards greater use of Work-Integrated Learning (WIL) as it is considered to have many benefits and a good theoretical base (Orrell, 2011).

There are a range of requirements for successful WIL recommended by Orrell (2011). At an institutional level these include a clear understanding of the purpose, value and expectations together with appropriate resourcing and integration with university support services. From an educational perspective students need to be prepared for the range of required tasks and expectations of employers, they need to be challenged and be given responsibilities and be provided with an opportunity for reflection on practice that is supported by the university. Finally strong relationships and effective communication between the university and the industry partners are required. In addition, it has been suggested that students need workplace experience during their studies to properly understand the importance of ethical practice and of going beyond simple compliance.

The wide range of companies and roles that graduates fulfil in those companies also presents difficulties for universities in providing the resources and support needed for really effective work experience and in providing clarity of expectations. For example over the summer break in 2015, approximately 150 students from the School of Civil Engineering at the University of Sydney were undertaking work experience and this was with about 80 different employers.

In response to some of the challenges mentioned above universities are adopting creative solutions to ensure students are able to benefit from greater knowledge and understanding of industry practices. These include formal industry based programs, cooperative education schemes, increasing use of industry projects, site visits (may be virtual) and the use of industry professionals as course lecturers. Currently these initiatives are adding to the 12 weeks full-time work. However pressures to graduate and ensure quality are leading to universities considering more formal instruction and a reduction in time spent in industry.

A further significant concern for the students and ultimately for the success of work experience is that increasingly students are accepting unpaid positions to enable graduation. While this may be acceptable for short periods of experience, 12 weeks without pay will create hardships for many students who often rely on casual jobs to support them through university studies. Work experience that is valuable and improves a student's job prospects would justify taking on an unpaid position, but the data on outcomes from unpaid work experience are mixed (Oliver et al, 2016).

Another issue is the increasing number of international students, all of whom are required to obtain work experience. At present this is largely occurring in their country of origin as Australian employers are reluctant to take on international students as there is little benefit in it for them. Perceived issues include language difficulties, lack of cultural understanding and visa limitations that prevent subsequent employment. British studies (Milburn, 2009) have also reported the exclusion of minorities and poor treatment of international students during work experience. It has been suggested that there is a significant national benefit to be obtained by giving international students Australian work experience.

In addition to these specific concerns, work experience has the potential to facilitate communication between employers and universities and to provide input into curricula. Traditionally engineering employers valued graduates for their technical knowledge and intellectual capabilities. However, there is now increasing emphasis on good interpersonal skills, practical work experience and commercial understanding. For universities the requirements for the latter has led to a reduction in the engineering science content of the courses, but the question of where and how the skills that make graduates work-ready are best developed is not resolved.

For all these reasons a better understanding of the nature and value of work experience of engineering students is required.

Context

At the University of Sydney both undergraduate and professional masters course engineering students are required to complete a zero credit point subject practical experience. Currently the subject has prerequisites which results in the practical experience generally occurring when the students have one year of study remaining. Students are expected to find an opportunity through their own efforts, and after 12 weeks or 420 hours of the experience to write a 6000 word report summarising their experience. The intention of the report is to get the students to reflect on the experience, its connection to the course, and the skills required of graduate engineers. They also have an opportunity to comment on their studies. At present the reports are only reviewed by the student's final year thesis supervisor and receive a simple pass/fail mark. Provided that the students have followed the prescribed headings and written in reasonable English, the reports are passed and no further action, such as providing feedback, is taken.

For several years the reports have been submitted electronically, stored and forgotten. This data resource contains information on the students' experience in terms of the skills and types of work. The majority of students report that the most important skills are related to communication, effective teamwork, information-seeking and use of IT. While academic staff feed this information back to the students, the value of building skills in these areas does not appear to be fully appreciated by the students until work experience. The data resource of past reports provides an opportunity to feed-forward this information using the student feedback. Also, the resource contains data from the whole cohort of how they value the course and has suggestions for possible improvements and innovations. There are obvious benefits to capturing and aggregating this data.

This paper provides the outcomes of a preliminary project which aimed to tap into this resource of information. The procedure used to mine the wealth of information which students record in their final year work experience reports is described and the data collated and discussed. From the results some suggestions are made to improve the educational and practical work experiences of students.

Review of Work Experience Reports

Process

407 work experience reports (WERs) submitted by prospective Civil Engineering graduates were surveyed from the periods 2010-2012 and 2014-2015. The reports were analysed by an algorithmic text-mining method to quantitatively gauge the type and extent of the skills

exercised by the students and the type of work undertaken. The methodology was based on an assessment of the frequency of occurrence of selected indicative words and phrases. This was achieved by extracting text files from the stored pdf files and processing these in a Matlab environment to identify the relative frequencies of targeted terms within the reports and the distribution of these frequencies overall. The quantitative algorithmic analysis was supported by the manual examination of individual reports to provide further understanding of the issues identified and a deeper insight into student experiences. In particular, the identification of the key skills most exercised and developed was extracted from students' answers in the 'Graduate Outcomes Table, Assessment of Learning Progression' forms, attached to individual reports.

The skills that were searched for were in the seven areas specified in the list of graduate attributes provided to assist students in writing their reports, namely:

- Design
- Engineering/IT specialisation
- Maths/Science Methods and tools
- Information Seeking
- Communication
- Professional conduct and teamwork
- Project management.

Data Summary

A majority of the work experience was undertaken by graduating students within Australia (76%) with 19% undertaking work experience in mainland China and the remainder across various other countries, all in the region of far-eastern Asia.

Most Exercised skills

With relation to the graduate outcomes, the skills students reported *most exercised,* shown in Figure 1, were: communication (42% of students), design (33%), and professional conduct and teamwork (28%). A notable discrepancy was observed in the trends of skill usage between students having conducted their experience overseas (predominantly China) and those having undertaken work experience in Australia. In particular, students having undertaken work overseas were more likely to report the Design, Maths/Science Methods and Tools and Engineering/IT specialisations as being more exercised and/or developed. In contrast the key skill of communication, which emerged as the most exercised skill overall was not significantly exercised in international work experience.

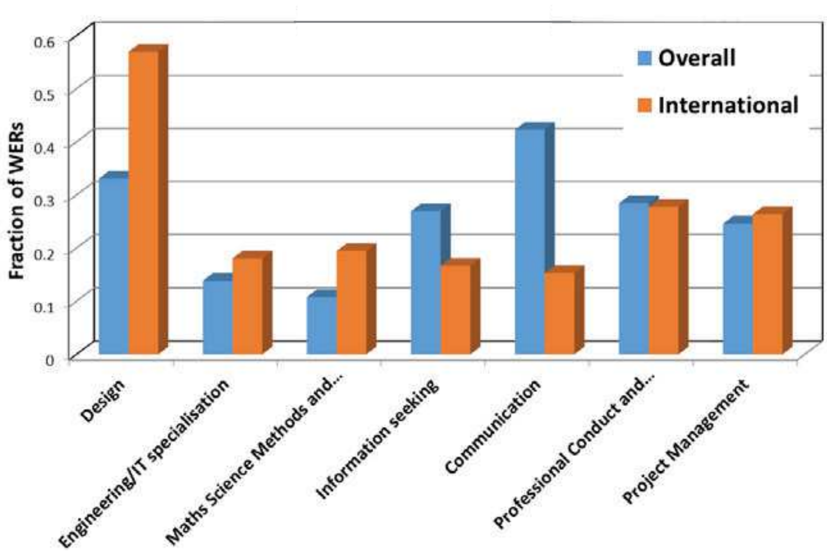

Figure 1: Most exercised skills

Most developed skills
A similar breakdown of data has been obtained for students' reports of skills *most developed*. It should be noted that not all student reports specified *skills developed* as separate to *skills exercised*. From an analysis of these data, communication and information seeking are most developed, with respectively 57% and 37% of students identifying these skills as having been among the most developed during their work experience. From a comprehensive review of student reports a notable observation is the lack of preparedness of students with regards to communicating with staff and managers across the various levels of hierarchy in the host organisation. However, the student experience is generally portrayed in a positive aspect with respect to these deficiencies and it is more common to encounter sentiments of achievement and professional development rather than conflict and friction arising from deficiencies in these attributes.

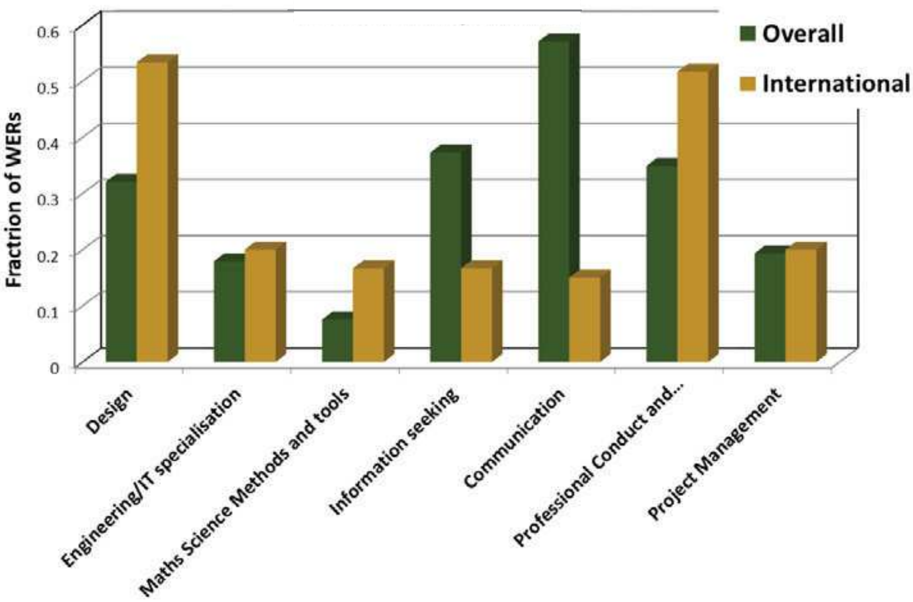

Figure 2: Most developed skills

Unexpected Outcomes
One interesting outcome of the work experience relates to the acquisition of practical experience in their chosen sector and the development of new insights into the various aspects of the field (*i.e.* "tricks of the trade"). In particular this relates commonly to "soft skills" not developed in their degree program. This finding highlights the importance of work experience and suggests that there would be benefit in including industry professionals in teaching and curriculum design within the earlier years of the degree, particularly in specialist civil streams.

Another finding was that work experience often led directly to the commencement of a career. Approximately 15% of students reported the possibility of ongoing employment arising from their work experience. These career opportunities involve either continuing part-time employment during their final year of study and/or opportunities for employment subsequent to graduation. It should be noted that self-employment was not reported by students, suggesting that the work experience is insufficient for students to consider entrepreneurism or independent career paths.

Analysis of the key skills

Communication
A high number of students identified *communication* as being the most important skill exercised and developed during practical experience. This was expressed as being most

important to develop as well as being the most common source of difficulties. For example, many students reported that asking for help and clarification regarding workplace duties was likely to cause disharmony.

Scope of Work
From numerous WERs, a varying degree of misalignment is evident between student and employer expectations in areas including the scope of the students' role, skill level, work activities and outcomes. This may derive in part from a lack of preparation on behalf of both students and the industry hosts prior to the commencement of work experience. This can be ameliorated by better preparation of the students by the University and by providing better information to the employers.

Task Related Skills
As a significant subset of the mismatch in expectations, it was in approximately 10 % of cases, reported that students were unprepared to carry out the technical tasks expected of them at the commencement of work (for example: modelling, management and site inspection duties). However, in a clear majority of cases, these initial difficulties were resolved, leading to positive learning outcomes rather than ongoing difficulties. In a few isolated cases skill deficiencies resulted in negative student experiences, in particular when accompanied by poor communication.

Teamwork and Interpersonal Conflict
Teamwork and dealing with the wide range of construction industry personnel was a concern for many students who reported friction in dealing with colleagues. This can be considered a distinct subset of the required professional communications skills. In particular conflict with construction labourers appeared to occur with not insignificant frequency. The teamwork experiences of students in their undergraduate degree had not prepared them for the full range of possible work-colleague situations that they might find themselves in. It is difficult to replicate this range in the course-work subjects, but some exposure to the full range of work-colleagues (and not just professional engineers) might help students adjust their expectations.

Sourcing Information
Students identified information seeking as a key attribute exercised (27%) and developed (37%) during their work experience. Across all civil engineering sub-disciplines and sectors, students reported encountering difficulties in acquiring and processing large volumes of information from sources such as work reports, standards and various technical documents. These are skills which can easily be included in the undergraduate curriculum. Information-seeking skills, such as internet finding and filtering, should be part of any undergraduate's toolkit and resources are usually easily available through the university librarians and archivists.

Student observations

Student growth
The work experience, by and large, caused the students to readjust their understanding of the multitude of aspects in the engineering profession, with most appreciation coming in the areas of risk management, client liaison, teamwork, communication, protocol development, documentation and reporting.

Student Career Intentions
Most students reported satisfaction with their current path and career intentions, though a sizeable minority expressed some re-assessment of their career plans. A similar scenario is encountered with respect to academic direction, with varying degrees of self-evaluation by students.

Degree reflections
Students reported the following recommendations/criticisms of their degree:

- Many (~8%) report a view that a greater emphasis should be placed on design education rather than mathematical calculations.

- The need for some teaching of AutoCAD software is frequently mentioned.

- More emphasis should be placed on acquiring job-relevant skills in the framework of their academic studies. The reports frequently mention the need for a greater emphasis on practical work and workplace-focused situations. Conversely a significant number of students reported that they would like to make changes to syllabi to emphasise the more academic aspects of the degree, as these theoretical aspects are less accessible through workplace based development.

While these results are insightful, more quantitative data would be required before any remedial action should be suggested or implemented.

Recommendations

The results of the data-mining available to this current research do not lead to incontrovertible findings, however they can be said to be indicative of what may be expected by further and better designed methods. With this in mind the following recommendations are presented:

1. Presentation of the final (6000 word) report should include a significant amount of form-based and on-line information. If well-designed, this could lead to an easily analysed database which could lead to the implementation of better preparation and experience for the students' work placement.

2. Coursework-based modules should be introduced in the UG program to better prepare students for their work placement experience. These could include the following breakdowns:

    a. Module: Communication skills, which would include:

        i. Professional workplace communication.

        ii. Effective and valuable communication with non-engineers.

        iii. Technical writing and reporting, including exposure to actual engineering reports to both technical and non-technical audiences.

        iv. Conflict avoidance and dealing with people of varied backgrounds.

    b. Module: Job skills, which could include:

        i. Career planning

        ii. Resume writing

        iii. Job seeking tools

        iv. Self-development awareness.

Conclusion

Industrial placement is a crucial component of the BE degree however the student experience can be improved through better preparation and support of students. The Work Experience report is a potential wealth of information about what can be done to make these improvements and thus create better prepared graduate engineers.

Preliminary analysis of historical reports presents strong evidence for continued development of student feedback mechanisms with a view to feed-forward important information on expectations to students. The reports also point to the need for better communication with industry representatives to clarify student skills and provide clearer expectations. In particular, there is evidence that greater integration of the Work Placement with the rest of the degree would lead to better outcomes for the students.

Based on these preliminary findings, there is justification for designing a better system for the submission of work reports whereby the data can be more easily analysed and provide more reliable feedback into the preparatory programs. Future development of this research is planned using form-based work report submissions which can inform the Practical Experience Placement program.

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Development of Global Competencies through Humanitarian Engineering Experiences

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SESSION S3: Integrating Humanitarianism in Engineering Education

CONTEXT Engineering graduates need to be prepared and empowered to undertake sustainability challenges and other global issues (Brown, Price, Turner, & Colley, 2016). Understanding the socio-environmental impacts of engineering design are critical to sustainable engineering practice. Engineers, especially engineering students, can have the tendency to rush into defining solutions early in the design process without considering the ethical and sustainability issues in design and decision-making processes. EWB Australia has developed student programs, i.e. EWB Annual Challenge and EWB Design Summit, that are designed to embed people-centred approaches into engineering, and help to prepare graduates for a world where they will face increasingly complex sustainability issues)

PURPOSE This study examines how students' perspectives on humanitarian engineering and global sustainability competencies develop based on their humanitarian engineering experiences.

APPROACH Students participated in the EWB Australia Annual Challenge in their first year of university study, and EWB Australia Design Summit in the second year of the engineering course. We interviewed students before and after their humanitarian engineering experiences, based on the EWB Design Summit in Cambodia. Pre- and post- student interviews on the EWB Australia Design Summit experience were conducted and analysed.

RESULTS Participants found that their immersion in the community and engaging with the community members resulted in a more empathetic approach to design, that they were able to communicate in more challenging environments, and that they gained a global perspective on the impacts of engineering design.

CONCLUSIONS Exposure and participation in humanitarian engineering experiences, like the EWB Australia programs, help students to realise that engineers operate in a holistic society and consider social factors that affect design. Facilitating students in these experiences will help to develop global competencies, by considering the social, environmental, and economic impacts of their designs, and improve their capacity to be a more well-rounded and global engineer.

KEYWORDS humanitarian engineering; design thinking; human-centred design;

Introduction

Engineering graduates need to be prepared and empowered to undertake sustainability challenges and other global issues (Brown, Price, Turner, & Colley, 2016). Understanding the socio-environmental impacts of engineering design are critical to sustainable engineering practice. Engineers, especially engineering students, can have the tendency to rush into defining solutions early in the design process without considering the ethical and sustainability issues in design and decision-making processes (Goncher & Johri, 2015). This paper focuses on the experiences of engineering students who participated a humanitarian engineering program, and the impact on students' perspectives of global issues in engineering. Reflections and insights from these experiences will be mapped to global competencies examines how students' perspectives on humanitarian engineering and global sustainability competencies develop based on their humanitarian engineering experiences.

Design Thinking in Humanitarian Engineering

Human-centred design (HCD), requires practitioners to empathise with end-users and identify the needs of those users rather than starting with solutions for the end-user. HCD has been identified as an effective approach to address poverty and development issues around the world (Kramer, Poreh, Agogino, 2017). Design thinking (Brown, 2008) provides framework for designers to perform needs assessment and encourages iterative design. Levine, Agogino, and Lesniewski (2016) suggest that design thinking is foundation to development engineering, and framed development engineering from a design thinking perspective to include development goals and constraints as well as business models for scaling (Levine et al., 2016). Figure 1 illustrates Levine et al.'s framework that applies elements in an iterative and overarching method, while incorporating on the various phases of HCD, e.g. ideation and prototyping.

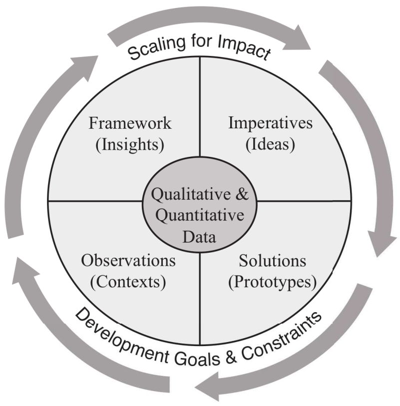

Figure 1: Design Thinking Framework (reproduced from Levine, Agogino, Lesniewski, 2016)

The human-centred design approach incorporates design thinking. HCD utilises the needs assessment in the discovery and emphasise phases, and encourages rapid prototyping (Brown, 2008) and communication with the end-users. We utilise the Design Thinking for Development Engineering (Levine et al., 2016) to this study's focus on humanitarian engineering experiences. The design phases related to insights, ideas, contexts, and prototypes and their relationship to development goals and constraints and scaling for impact will be important to highlight how design thinking in humanitarian engineering can be used to analyse students' experiences.

The context of this study is a humanitarian engineering experience that incorporates the human-centred design approach to expose students to ethical, sustainability, and development issues in engineering. The follow section provides a description of the experience, and the role of students and academics in the summit.

Engineers Without Borders Design Summit

Engineers Without Borders Australia (EWB) has developed a number of programs that are designed to develop human centred design skills in students. These include the EWB challenge and the EWB humanitarian design summit program. Both programs require students to actively engage with the human centred design (HCD) process. The learning outcomes of these programs also help students develop global competencies relating to humanitarian design, as outlined in Klein-Gardner and Walker (2011).

The EWB challenge is a first-year engineering design subject offered in most universities across Australia and New Zealand. Students undertake a semester long, team-based, design project to address a design brief. This “design brief is based on a set of sustainable development projects identified by EWB with its community-based partner organisations” (EWB, 2017a). This provides students with an opportunity to engage with the HCD in a theoretical context, to begin to understand the process and to develop their understanding of humanitarian centred design. [University] offers this program as a required course for all first-year student engineers as a project based learning subject. Unique to [university], each team of student engineers is assigned an academic mentor who works exclusively with that team. Student engineers are encouraged to develop their own understanding of the design areas through research and exploring [university’s] curriculum, enabling a deeper understanding of the subject matter in a context reflective of industry practice.

The EWB humanitarian design summit program provides an opportunity for engineering students to experience humanitarian engineering in a realistic context. The program consists of an intensive two weeks overseas, working with EWB community partners to understand their culture, context and development related challenges. Students are required to actively engage with the HCD process and ultimately identify opportunities for these communities to address their development goals. The programs operated with a strength’s based approach and focus on developing long term partnerships between EWB and local community organisations in-country. Students are accompanied by facilitators from both industry and academic backgrounds, “who guide the participant learning experience and ensure the safety and wellbeing of the group” (EWB, 2017b).

Eight students were accepted to attend the EWB humanitarian design summit to Cambodia in June and July 2017. These students represented a variety of gender, age and cultural backgrounds. All were either first year or second year students of [university’s] Engineering’s bachelor of civil engineering program. Each of these students had already completed the EWB challenge as a part of their first-year studies. Two academic staff members were also selected to accompany the student engineers on the design summit as academic fellows. The role of the academic fellows being to “facilitate the learning and educational experience of student participants” (EWB, 2017b). Prior to embarking on the design summit each of the student engineers completed a series of questions on their understanding of development and humanitarian engineering.

The summit commenced in Phnom Penh with the first four days spent developing an understanding of Cambodian culture through a range of exercises including a series of pre-placement workshops run by the facilitation team. These workshops introduced participants to the HCD process as well as some key considerations of humanitarian engineering, sustainability, and the strengths based approach to development. Students also had a chance to apply what they had learnt through a series of exercises, engaging with the local community. One of the key considerations that was stressed at this stage was the need to focus on understanding the context and culture of Cambodia before starting to define solutions, a tendency that engineering students are known to exhibit (Goncher & Johri, 2015).

The middle stage of the design summit consisted of a home-stay experience in a rural Cambodian village. This provided an opportunity to experience the realities of life in a developing rural community. Students undertook activities designed to develop cultural understanding of the realities of life for these people. Activities including participating in agricultural practices, food preparation and cultural events. Students also observed examples of community events, cultural practices, educational practices, employment opportunities, health and hygiene practices, food preparation and waste disposal. They conducted interviews with members of the village using translators to develop a deeper understanding of what they were observing. These activities were designed to provide a wealth of learning opportunities as well as a practical application of the 'discover' and 'empathise' phases of the HCD process. Students were encouraged to reflect daily on what they observed in the communities and to link their reflections to their evolving understanding of development and humanitarian engineering.

The remainder of the design summit was spent taking the knowledge gained during the community visits to develop potential solutions for the community. Students formed into teams, collating the information gained during the 'discover' and 'empathise' phases, which they then fed into the 'ideate' and 'prototype' phases of the HCD process. Final design solutions were developed and presented to representatives from each of the communities that were visited during the summit, these representatives provided feedback on the practicalities and potential for implementation of the design solutions produced by the student teams. This process provided students with an opportunity to complete the HCD process and develop an understanding that the best design intentions may not always be appropriate for their intended stakeholders.

Upon returning from the design summit each of the students were asked to reflect on how their understanding of development and humanitarian engineering had changed because of their experience.

Both the EWB design challenge and the EWB humanitarian design summit programs provide a wealth of opportunities for students to develop their knowledge of humanitarian engineering and to implement the HCD across a range of contexts. As such these programs address the [students] graduate learning outcomes of 'global citizenship' and 'sustainable practice' as well as the Engineers Australia (EA) stage 1 competency 1.6 c: 'appreciate the social environmental, and economic principles of sustainable practice'. Students also have the opportunity to develop their understanding of HCD in the context of some of the sustainable development goals, namely: 'clean water and sanitation', 'affordable, clean energy', 'industry, innovation and infrastructure' as well as 'sustainable cities and communities'.

Methods

This study examined how students' perspectives on humanitarian engineering and global sustainability competencies develop based on their humanitarian engineering experiences. Participants in this study included six males, two females; of the six participants, two participants had cultural backgrounds from a South East Asian background. These two participants were born in South East Asia before moving to and living in Australia, and experienced similar living experiences to the immersive cultural experiences as part of the Design Summit. Design Summit participants in this study received course credit for their participation and completion of assessment tasks, however the participation was not a requirement of the course completion, or requirements. All participants that responded to the interviews and were part of the summit as part of the Engineering course, are included as participants in this study.

We collected student-produced documents, such as reflections, related to the EWB Design Summit. Pre- and post- student interviews and reflections from the EWB Australia design summit was analysed based on the coding structure in Table 1. Students' perspectives on their experiences of global competencies, as they relate to humanitarian engineering and development,

The researchers analysed eight student participant's pre- and post- summit responses. Students answered the question prior to the beginning of the design summit, and then immediately after the community stay and conclusion of the summit.

Table 1: Humanitarian Engineering Experiences Coding Structure

Code	Sub-code	Definition
Human Centred Design		Design thinking/ understanding the problem, context, needs, and prototyping solutions
Humanitarian Engineering		Reference to humanitarian engineering, or humanitarian engineering contexts
	Development, Disability	Humanitarian Engineering encompassing more than technology or disaster relief (Smith, Compston, Male, Baillie, & Turner, 2016)
	Social, Cultural, and Environmental	Relevance of social, cultural, and environmental context to engineering (Smith, Compston, Male, Baillie, & Turner, 2016)

The coding structure was based on previous literature regarding design thinking in development engineering (Levine, Agogino, & Lesniewski, 2016) and relevant engineering education work in humanitarian engineering (Smith, Compston, Male, Baillie, & Turner, 2016).

Results

The pre-summit and post-summit interview questions prompted students to define engineering and humanitarian engineering. The purpose of the study was to examine if the summit experiences contributed to students' development in engineering competencies. The analysis identified students' perspectives on engineering prior to, and after the design summit experience.

We found that prior to the summit 50 percent of the participants' definition of engineering included reference to an engineer's/ engineering's role in society, e.g. Participant 1: *"Engineering to me is basically putting together skills you've learnt from technology and maths and trying to incorporate that into addressing a problem that's beneficial to society.*" Twenty-five percent of participants did not refer to engineering from a societal or people/ community-impacted, e.g. Participant 4: *"engineering is a profession that deals with problem solving by individuals with specialised knowledge and skills for problems of high complexity and requires a very high level of understanding."* The other 25 percent indicated a change in the participants' initial definition from a professional-oriented job to include the role of engineering in society, e.g. Participant 5: *"Initially thinking it being more of a profession, and now considering it more of a mindset and more of an approach to complex solutions, as well as simple solutions. But more in the aspects of technical problems which are experienced by those in the community that may not have specific knowledge of what the solution might be or how to approach that solution*."

Sustainable decision-making processes that consider appropriate sustainability and ethical issues are key to developing appropriate technologies and designs that create positive change in developing communities. Students viewed the role of humanitarian engineers to include empathising with the communities, and did not include disaster relief based on their post-summit responses. Below is an example of a participant response that highlights the relevance of the social and cultural contexts.

“HE’s have a responsibility to ensure their impact is that of a positive nature, that includes paying attention to what a community needs as opposed to what may be considered as a requirement by an outside individual or entity. HE’s must be very sensitive and respectful to cultural traditions by enriching themselves with cultural knowledge before attempting to empathise with communities and explore design opportunities. An emphasis is to be placed on empathy, one of the essential tools required for a humanitarian engineer.”

Students who worked with the community partners in during the Design Summit Program in Cambodia utilized the context of the community when defining the design opportunity and were more sensitive to the end-user requirements. Experiences, such as working with the community members in the corn fields or interviewing the school teacher, clarified the importance of end-user requirements. The Summit’s pre-community activities introduced students to the phases of the HCD. For example, the empathise phase activity facilitated students to interact with people that could be user of a proposed design idea.

As part of the EWB Design Summit, students engaged in activities, that encouraged them to think about empathising with the end user, an example of students designing improvements for Tuk Tuk drivers’ transportation solutions is seen in Figure 1. Other program graduates reflected that the Design Summit allowed them communicate in more challenging situations, and that they gained a more global perspective on the impacts of engineering design.

Figure 2: Empathise Design Phase Activity

Design Summit engineering student participants reported that their immersion in the community and engaging with the community members, resulted in a more empathetic approach to design where they defined the design opportunity from the user’s perspective rather than their own perspectives.

The post-summit responses analysed participants’ perspectives on engineering and development to reflect any perspective changes in the engineering global competencies. The flowing quote from Participant 4 highlights a development in this students’ perspective of their ability to understand the implications of cultural differences and an appreciation of other cultures (Klein-Gardner, and Walker, 2011).

Participant 4: “My definition of development has shifted somewhat, but I believed that if people had access to running water and sanitation, electricity, education and health services, then they would be considered developed. This idea has changed a little though and broadened. While these are all still good indicators, they don’t represent true development. Given the Cambodian context, there were elements of these

> indicators which did exist in all the communities that I saw, from the city, small towns, and even in the tiny village communities. For me, having observed the presence of many of these key indicators and noting the absence of others, it became apparent that these alone did not signify development, especially in instances where there were obvious external inputs. My definition of development is one where these facilities and services still exist, but they are instigated and installed, developed and improved by the local people and not by an outside source. And to this end, if the local community can facilitate their own improvement, then they are developing.

The post-summit responses of participants' perspectives on engineering and development focused on how the experience of the summit incorporated participants' reflection of HCD, Sustainability, and how the experiences allowed students to communicate across cultures and deal with ethical issues. The EWB- supported experiences, in conjunction with the project-based learning approach, provide a scaffolded opportunity for students to experience realistic humanitarian engineering design experiences that contribute to the development of graduate global competencies.

Discussion

Several of the student engineers who attended the design summit have cultural backgrounds that are of a similar context to that experienced in Cambodia. This may have helped them to develop a deeper understanding of the culture and context that they experienced on the design summit as opposed to those students with a more western based cultural background.

One of the key points that was stressed continuously throughout the design summit by the facilitation team was that the aim of the summit was not to apply practical engineering skills but to develop a deeper understanding of another culture and their development related opportunities. In general, the students were mindful of this approach, engaging with the community visits by trying to understand rather than seek solutions.

Through attending the design summit closely after completion of the EWB design challenge, the students were well prepared to actively engage with the HCD process.

Limitations to the study presented in this article are a small subset of participants, compared to students that participated in both the EWB challenge, Design Summit, and are included in the CSU Engineering course curriculum. As part of the qualitative research analysis structure, we aim to provide representative sample, focusing on a particular context in more detail. We also acknowledge the limitations of the context of the study that provides an immersive experience for students within a specific engineering development context.

Recommendations for the engineering education community that are interested in implementing results from the participants, would be to develop design activities that incorporate societal factors into engineering design earlier in the curriculum. Incorporating societal factors into engineering design (Smith, Compston, Male, Baillie, & Turner, 2016) are important to developing students' global competencies. Students who are exposed to HCD and other sustainable design practices should benefit from additional experiences that expose students to various factors, e.g. societal, environmental and cultural, impacting engineering design. The immersive experiences helped students to be sensitive to end-use requirements, gain global perspective on impacts of engineering design, and communicate in more challenging environments, are impactful to developing global competencies. Recommendations for contexts that are not able to provide immersive experiences would be to provide activities that allow, and encourage, students to consider the social factors that impact design and how students should incorporate other environmental and cultural factors into engineering design.

Conclusion

Engineers operate in a holistic society, where a concern for the environment and the user is key to engineering design. Facilitating students to use a human-centred design approach, by considering the social, environmental, and economic impacts of their designs, improves their competency to be a more well-rounded and global engineer. Experiences, such as the Design Summit, where students are exposed to opportunities that can allow them to utilise or apply global competencies as humanitarian engineers is beneficial toward their overall professional identity as an engineer.

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Defending interpretivist knowledge claims in engineering education research

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SESSION C5: Systems perspectives on engineering education

CONTEXT In interdisciplinary research, tacit epistemological differences can influence how research is interpreted and judged as trustworthy or otherwise. One example is in education research in engineering. A complication in the development of engineering education research as a field is that many of its practitioners have moved into education research from a background in traditional engineering, underpinned by a positivist epistemology with established criteria of research rigour. However, an arguably similar consensus has not been reached for criteria of research quality in education, at least not in inter-disciplinary areas like engineering education. One consequence is that researchers from such a positivist tradition can be dismissive of interpretivist research findings, and only find positivist research trustworthy.

PURPOSE How to defend interpretivist knowledge claims in engineering education research?

APPROACH Walther, Sochacka, and Kellam (2013) used an analogy with quality management in engineering to develop a process-oriented framework for interpretive research quality. Instead of judging only the quality of research outcomes, as is typical in positivist research, they focused instead on the processes of both making and handling data.

In this paper, this framework is unpacked and used to defend the results of the authors' previously published phenomenographic study of lecturing (Daniel, 2016; Daniel, Mann, & Mazzolini, 2016).

RESULTS In this paper, the reliability and validity of the outcomes of a previous phenomenographic study of ways of experiencing lecturing are established. This is achieved through reference to established conventions in phenomenographic research, thick descriptions of how the data was collected and analysed, and comparison to the results of similar studies, all within the framework of interpretivist research quality developed by Walther et al. (2013). Such thick descriptions of data collection and analysis are often omitted from phenomenographic publications, whereas detailing this process can lend weight to such research's reliability.

CONCLUSIONS Interpretivist methodologies have an important role in engineering education research. By taking pains to establish the validity and reliability of interpretivist research outcomes, it is hoped they will be accepted more widely amongst researchers, regardless of whether they come from a positivist or interpretivist background.

KEYWORDS Research quality, epistemology, interpretivist

Introduction

"Show me a cultural relativist at 30,000 feet and I'll show you a hypocrite"

Richard Dawkins
River out of Eden (1995)

In inter-disciplinary research, tacit epistemological differences can influence how we interpret research and judge its trustworthiness. One example is in engineering education research, and in STEM education research in general. A complication in the development of STEM education research as a field is that many of its practitioners have moved into education research from a background in traditional science, underpinned by a positivist epistemology with established criteria of research rigour. However, a similar consensus has not been reached for criteria of research quality in STEM education research. One consequence is that researchers from a positivist tradition can be dismissive of interpretivist research findings, and only find positivist research trustworthy. This is illustrated in the above quote, and in the following excerpt from an interview conducted with a physics lecturer (Daniel, 2016):

> *I went to a talk by Eric Mazur that made me more aware that there is actually not just some theories on why active learning might be better, but a lot of hard-nosed detailed statistically significant research, at first-year level anyway, on why it is better … and that was really what made me aware that* ***this isn't just teaching and learning specialists wittering on about the latest pedagogical craze, this is well backed by hard evidence with good p-values*** *[Zorro, p. 32]*

In a positivist tradition, research quality is typically judged by the validity and reliability of findings. Validity can be defined as the "agreement of the results of a measurement with the true value of the measured quantity" and reliability as the "repeatability" of measurement (Sirohi & Radha Krishnan, 1983). With their emphasis on measurement, validity and reliability are sometimes operationalized as accuracy and precision.

But how to make sense of these concepts in interpretivist research, where there are no objective 'true values', and the complexity and uniqueness of social systems belie the possibility of exact repeatability?

In social science research, there is a long tradition of exploring these questions of interpretivist research quality (e.g. Guba (1981), Krefting (1991), and Schwandt, Lincoln, and Guba (2007)). However, in this study we used a new framework for research quality that is perhaps more appropriate and accessible for engineering educators, as it attempts to build a bridge between engineering practice and interpretivist research.

Walther et al. (2013) used an analogy with quality management in engineering to develop a process-oriented framework for interpretive research quality. Instead of judging only the quality of research outcomes, as is typical in positivist research, they focused instead on the processes of both making and handling data. They reframed reliability as the extent to which random influences on the research process are minimised, and unpacked validation into four different aspects, centred around the question of "whether the researcher sees what they think they see" and how they conform to meaning conventions in reporting their work to the relevant research community.

In this paper, we will describe this research quality framework and give contrasting examples of how it can be used to characterise quality interpretivist research. Then we will explore how it was used to defend the first author's PhD phenomenographic research into lecturers' different ways of experiencing lecturing, in the epistemological cold-war battleground of engineering education.

Reliability and Validity

Scientific Research Quality

Scientific research quality is generally evaluated by its reliability and validity, operationalised as precision and accuracy (Figure 1). The goal is to have results clustered tightly around the centre of the metaphorical target. That is, results that are both precise and accurate, as represented in the bottom right diagram.

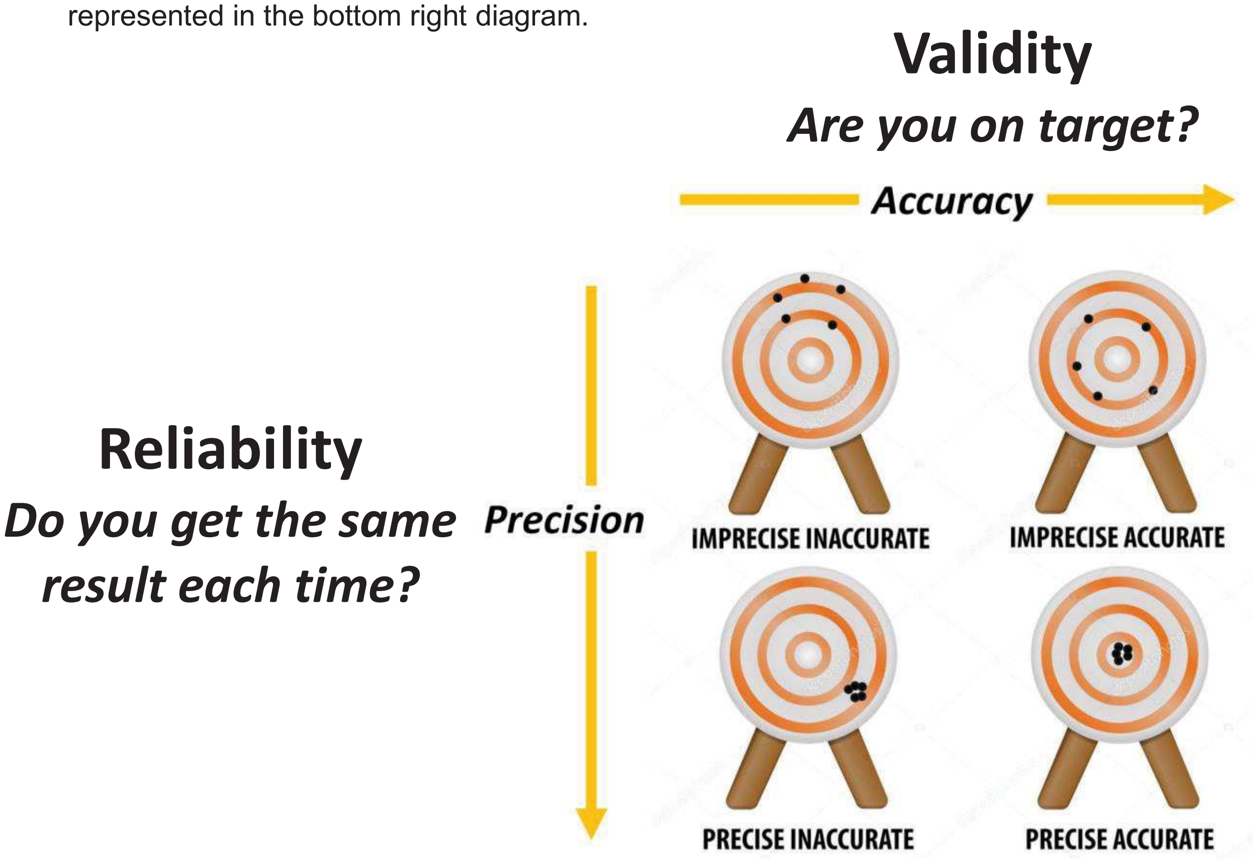

Figure 1: Characterising scientific research quality

Results that are on-target but only clustered loosely, as in the top right, are said to have a large random error. This could reflect a low-resolution measuring instrument, or perhaps a relationship affected by factors you haven't considered. For example, although a person's height is a useful predictor of their weight, the impact of other relevant variables means that if you measured the weight of a number of individuals with the same height, there would still be considerable variation.

Conversely, results that are tightly clustered but off-centre, as in the bottom left, indicate either a zero or systematic error. One recent high-profile example of such precise but inaccurate measurements was the six-sigma result of neutrinos traveling faster than light (Adam et al., 2012), which was later found to be spurious due to a subtle systematic error. Another example is the crash of the NASA Mars Climate Orbiter in 1999, because one team was measuring thrust in imperial units, but another team was assuming these values were in metric units (Grossman, 2010).

Research questions like "What is the speed of neutrinos in a vacuum?", or "What is the relationship between height and weight of Australian adults?", are about investigating objective reality and collecting 'hard' data. However, typical education research questions, like "What does 'great teaching' mean to different people?" or "How do different students perceive successful research supervision?" are instead about the researcher making sense of subjective experiences. That is, they reflect an interpretivist, rather than positivist, epistemology. If the same criteria of positivist research quality are applied to interpretivist education research, asking questions like “Do you get the same result each time?” and “Are you on target?”, one may be tempted to conclude, like Zorro in the above quote, that such research is meaningless and “just teaching and learning specialists wittering on about the latest pedagogical craze”.

Characterising interpretivist research quality

Walther et al. (2013) developed a framework for interpretivist research quality, adapting the concepts of positivist research quality to the interpretivist domain (Table 1). Instead of the positivist focus on judging only the quality of research results, they applied an analogy with quality management and focused on the research processes of making and handling data.

Table 1: Frameworks of research quality

	Positivist research	***Interpretivist research*** ***(Walther, Sochacka et al., 2013)***
Focus	Results	*Processes* *cf. Quality management*
Reliability	Do you get the same result each time? **No random error**	*Mitigating random influences on the research process* ***Process reliability***
Validity	Are you on target? **No systematic error**	*Does the researcher see what they think they see?* ***Theoretical, procedural, communicative, and pragmatic validation***

They interpreted reliability as ‘process reliability’, and unpacked validation into four different aspects (Table 2). Note that they used the term ‘theory’ to mean the researcher’s interpretation or ‘sense-making’ of the phenomenon under investigation.

Table 2: Four different aspects of validation (Walther et al., 2013)

Aspect	**Related to:**
Theoretical	the fit between the social reality under investigation and the theory generated
Procedural	features of the research design that inherently improve the fit between the reality studied and the theory generated
Communicative	the integrity of the interlocking processes of social construction with the relevant communication communities
Pragmatic	the compatibility of theoretical constructs with empirical reality

As in positivist research, the goal is always to conduct valid and reliable research. To help demonstrate what valid and reliable interpretivist research looks like, we will first show what it is not (cf. variation theory (Bussey, Orgill, & Crippen, 2013)), by giving some counter-examples of low-reliability and low-validity research.

Low reliability example

If, for example, a researcher had to go through a dozen research assistants before finding one that agreed with her thematic coding of some interview data (as has been reported anecdotally), the research would have low process reliability. The analysis would arguably be more a reflection of the idiosyncrasies of the researcher, than the views put forward in the interviews.

Low validity example

If a researcher were to use student feedback surveys with the belief that this was a measure of teaching quality, this would be an example of low validity research – the researcher would not be seeing what they thought they were. Student feedback surveys are more a reflection of the presenter's charisma or fluency (Carpenter, Wilford, Kornell, & Mullaney, 2013; Naftulin, Ware, & Donnelly, 1973), or the respondents' biases (MacNell, Driscoll, & Hunt, 2014), than teaching quality or student learning.

Low reliability and low validity example

Were a researcher to investigate what it means for research supervision to be a success, by interviewing students, including some of her own, about their perceptions (as has been reported anecdotally), this would be an example of research that is both low reliability and low validity. Because of the unexamined power dynamic between the supervisor and her students, the research would not be valid. Further, because of the mix of students, with some being her own, and some not, this would arguably be an 'unmitigated random influence on the research process', or in other words meaning that the research had low reliability.

As opposed to these low reliability and low validity examples, in the following section we argue for the high reliability and high validity of one of our previous studies.

Establishing the reliability and validity of our previous work

We previously conducted a phenomenographic investigation of experiences of lecturing, asking 'What are the different ways of experiencing lecturing?'. Although other studies have investigated different experiences of teaching in general, this was the first study with a specific focus on lecturing. The results of that investigation are explored in detail elsewhere (Daniel, 2016; Daniel et al., 2016). In summary, we identified the following five qualitatively distinct ways of experiencing lecturing, framed by three themes of experiencing awareness: student diversity, interaction, and lecture purpose.

1. Lecturing as soliloquy
2. Lecturing as connecting meaning
3. Lecturing as cultivating individuals
4. Lecturing as transformatively co-creating
5. Lecturing as enacting research

Claims of research quality in engineering education often remain tacit. In the first author's PhD thesis (Daniel, 2016), the five criteria of the Walther et al. (2013) quality research framework were explicitly addressed in multiple ways, for both *making* and *handling data*.

In the following sub-sections, representative examples of how this was achieved are given for each of the criteria, to give a flavour of how this framework can be used in practice. For the sake of brevity, in each case the quality of the research process of only either *making data* or *handling data* are discussed. The first person 'I' is used to indicate it was the first author's analysis and interpretation.

Theoretical validation

Walther et al. (2013) describe this quality criterion (p. 640) as answering:

> *Do the concepts and relationships of the theory appropriately correspond to the social reality under investigation?*

In other words, this aspect focuses on the question: to what extent does the knowledge produced by an investigation relate to the empirical phenomenon in question?

Making the data

In our study, this was addressed by purposely recruiting as diverse a sample as possible. In phenomenography, the goal is not to gain a representative sample, but instead to capture a wide pool of experiences of the phenomenon in question. For this investigation into lecturing, the dimensions along which we sought to maximise diversity included gender, university context (regional versus urban, research-focused versus technology-focused), discipline, and years of lecturing experience.

Furthermore, the object of study was not lecturing practice *per se*, for which perhaps an observational study would be most appropriate. Instead of such a first-order empirical study, the object of study was understanding the different ways in which lecturing is *experienced*. Although the extent to which it can do so is innately limited (Säljö, 1997), the best tool we have for this is analysing the different ways people talk about the phenomenon, to deconstruct what is salient to them about the phenomenon. Thus, semi-structured interviews were used.

Procedural validation

Procedural validation is about making clear what aspects of the research design improve the fit between the social reality and the interpretation thereof.

Handling the data

In analysing the transcripts it was important to try to identify instances in each transcript, and in the pool of transcripts as well, of each critical variant to ensure that my interpretation was not based on some idiosyncratic analysis of one decontextualised utterance but grounded in the context of the transcript and the pool of transcripts.

In addition, when I had felt I had identified some ‘essence’ of a transcript after reading it, I made sure I could identify supporting quotes to defend my knowledge claim. I had to always question my interpretations, and purposely look for and consider disconfirming instances, to limit the extent to which I was projecting my biases on to the data. This process of cyclically evaluating conjectured interpretations against the data is sometimes called the ‘constant comparative method’ (Glaser & Strauss, 1967).

I used a number of strategies to critique my own interpretation and decision-making process of analysis. I kept a detailed record (cf. Chapter 6 of my thesis) of decisions and interpretations and sought always to evaluate them against the transcripts and disregard intuitive interpretations that I could not defend without quotes. I was aided in this process by two critical friends (Costa & Kallick, 1993) who helped shape the analysis by challenging me on points that I had glossed over or not backed up with supporting quotes. If I could not argue from the quotes for a particular interpretation, it was disregarded.

Communicative validation

This criterion refers to the extent to which meaning and interpretation is communicated with different stakeholders in the research process: participants, the research team, education practitioners, and other researchers and the literature more broadly.

Making the data

At the beginning of each interview, through both the consent form and a quick spoken introduction, I would describe my research project and highlight that I was interested in *their* experiences of lecturing, and that there were no ‘correct’ answers. If participants asked what I meant by lecturing, I would explain that I was asking about what happened when they had a lecture on their timetable, or about what happened in the lecture hall. In this way, I ensured that we were talking about the same phenomenon, but avoided projecting any of my own judgements or understandings about lecturing.

As I wrote on my interview protocol as a prompt for myself, I would ‘guard against assuming any terms they say’. In practice this meant that I would avoid paraphrasing participants’ ideas back to them to seek their confirmation, which would involve recasting their ideas through my awareness, or not checking terms at all, which would imply me making assumptions about meanings of terminology. Instead, when relevant concepts were referred to, I would neutrally probe them, using questions such as “what do you mean by that?” or “can you give me an example?”, with the assumption in the interpretation that the provided example is an exemplar of that concept, that for the respondent it epitomises the features of the concept important to them. Sometimes, I would simply repeat their words with an upward inflection – a non-judgemental way of asking them to elaborate on the meaning of a particular term or phrase.

Using these strategies I communicated with participants my motives for the research, and clarified any ambiguous terminology.

Pragmatic validation

Walther, Sochacka et al. (2013) characterise pragmatic validation as the “process of determining whether the theory and constructs used or developed in a particular study can withstand prolonged exposure to the empirical reality” (p. 647). That is, do the results actually make sense. In phenomenography for example the goal is to describe variation, therefore the results should actually show some variation.

Handling the data

My analysis was pragmatically validated in several ways.

The analysis process was meaningful for me
Similar to how the participants found the interview process a useful reflective device, as a lecturer myself, I found the interviews and subsequent analysis a prompt for reflection on my own practice and understanding. It also prompted me to reflect on issues outside of teaching, as well as helping me make sense of other education contexts in new ways. I explore these reflections in detail in my thesis, but overall I can assert that the process has been meaningful for me.

Phenomenographic assumptions validated by findings
Phenomenography assumes that there is a coherent hierarchy of categories of description that relates the variation in how participants’ transcripts reflect the different ways they experience a particular phenomenon. I found such a hierarchy, and therefore my study is pragmatically validated.

Potential application to professional development
Beliefs about teaching are a necessary, but not sufficient, component of successful pedagogical reform (Henderson, Beach, & Finkelstein, 2011). It is my hope that this study will contribute to the discussion about teaching beliefs in a meaningful way by prompting lecturers to reflect on their practice, and perhaps eventually be incorporated into future effective professional development programs for lecturers, thereby incidentally demonstrating its pragmatic validity.

Process reliability

Within a positivist epistemology, reliability refers to the consistency of repeated measurements. In an interpretivist paradigm, the complexity and uniqueness of different participants and contexts are central, and so the criterion of repeatability is no longer applicable. Instead, Walther et al. (2013) adapt the idea of reliability into interpretivist research as the extent to which the research process is independent of random influences, including the idiosyncrasies of the researcher. They advocate for the "development and explicit documentation of dependable procedures in making and handling the data" (p. 649).

Making the data

I provided 'explicit documentation' of my phenomenographic data collection process in my thesis (Daniel, 2016), and summarise it briefly here.

I conducted two pilot interviews, which were not used in the analysis, which I recorded and reviewed with my supervisors to refine the interview protocol and my interview technique. When debriefing with one of the pilot interview participants, and analysing with him to what extent I had allowed my own awareness to influence the direction it took, he commented poetically that "you opened a canvas for me to paint my understanding on".

I recorded the interviews on a digital voice recorder, then had them transcribed by a professional transcriber (except for two interviews which I transcribed myself), and then subsequently verified the transcription myself, to correct phonetic substitutions or other transcription errors.

Conclusion

Vouching for the quality of interpretivist research processes is sometimes overlooked compared to the review processes in place for judging research outcomes, typically published as conference or journal papers. Quality research outcomes are predicated upon quality research processes, but claims of the latter are most often implied rather than made explicit in engineering education research. This work makes an important first step in interpretivist engineering education research by using a systematic quality framework, developed through an analogy with engineering quality management, to explicitly argue for the reliability and validity of a phenomenographic education research study.

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Disability Inclusion in Australian Engineering Education

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CONTEXT

It is a universal human right for those with a disability to have equitable access to higher education (UN General Assembly, 2006). However in Australia and many other countries the participation and completion rates of people with disability in higher education remain significantly lower than for people without disability.

PURPOSE

To consider the current state in Australia of inclusion in higher education for people of working age with a disability and review the current level of inclusion in STEM higher education at one of Australia's public universities.

APPROACH

A survey and analysis of available statistical data for higher education and engineering education was performed focusing on disability and inclusion of students with disability.

RESULTS

This paper presents the statistical status of disability inclusion of higher education in Australia (for public universities) and of STEM inclusion at one of Australia's public universities.

CONCLUSION

Disability inclusion in higher education is gaining increasing attention in Australia and internationally. For almost 70 years there has existed an underlying universal human rights obligation for the majority UN member nations to ethically ensure education access and inclusion for all. It is only within the last 25 years in Australia that this principle has been specifically embodied in legislation and including higher education.

Gaps in research on disability inclusion in Australia and internationally ensure difficulty in precision when attempting to determine the actual prevalence rates of student disability and identifying the major barriers to higher education access and engagement for persons with disability.

KEYWORDS

Disability, inclusion, STEM, Australia

Introduction

It has been almost seventy years since the United Nations proclaimed its Universal Declaration of Human Rights (UN General Assembly, 1948) in which Article 26(1) states that, “Everyone has a right to education,“ and,

> *“Technical and professional education shall be made generally available and higher education shall be equally accessible to all on the basis of merit.”*

This all-inclusive statement makes no specific reference to the relative physical and/or mental abilities of all assessed as being of equal merit to be considered on an equitable basis and for many member nations of the UN, including Australia, the existence of corresponding policies, legislation, standards, regulations, and resourcing to action these committed principles to uphold the rights of persons with disabilities (physical and/or mental) is much more recent. In Australia, the binding legislation for (all) education providers has been in existence for only twenty five years as Commonwealth legislation, namely the Disability Discrimination Act 1992 (DDA) (Department of Education and Training, 2017b) and its corresponding Commonwealth regulatory standards, Disability Standards for Education (Standards) which were first issued in 2005 (Department of Education and Training, 2017c).

More recently, in 2006, the United Nations adopted the Convention on the Rights of Persons with Disabilities (CRPD). This currently has 160 signatories including Australia (UN General Assembly, 2006). The CRPD’s stated purpose (ibid) is to:

> *“…promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for this inherent dignity.”*

Article 24 of the CRPD addresses education and the obligation of all signatories to ensure that persons with disabilities are not excluded from “the general education system” although the scope of the convention is limited to primary and secondary education for children. In Australia the DDA and its accompanying Standards are inclusive of post-secondary (higher) education, specifically addressing the right of people with disability to be protected against discrimination in education (Department of Education and Training, 2017b):

> *“…enrolling or studying in a course at a private school or public school, college, or university.”*

The Standards define the obligations of education providers in Australia to provide reasonable adjustments where necessary to include individual students with disability where “adjustment” is defined as (Department of Education and Training, 2017c):

> *“...a measure or action taken to assist a student with disability to participate in education and training on the same basis as other students.”*

And “reasonable adjustment” is defined as (Ibid):

> *“…if it achieves this purpose while taking into account the student’s learning needs and balancing the interests of all parties affected, including those of the student with disability, the education provider, staff, and other students.”*

There exists no requirement for adjustments or changes to accommodate the needs of any individual student with disability if this poses “unjustifiable hardship” on the education provider (Department of Education and Training, 2017c).

In 2011 the Council of Australian Governments (COAG) ratified and issued the National Disability Strategy 2010-2020 (Department of Social Services, 2011) and in 2012 the Australian Government announced the creation of the National Disability Insurance Scheme (NDIS) which is currently being rolled out nationwide (Gillard, 2012)

In Australia, the legislative and regulatory environment for persons with disabilities appears to invoke stakeholder theory (assessment of the respective impacts on all relevant stakeholders) to determine what is deemed reasonable as obligatory adjustment or change by any provider of services (including education services) so as to be inclusive of persons with disability.

Disability in Australia

Disability is defined in Australia by the DDA and it includes total or partial loss of bodily (physical) or mental functions as well any disorder, illness, or disease that affects a person's learning, perception of reality, emotions, judgement, or behaviour (Department of Education and Training, 2017b).

The DDA intentionally seeks to be broad in defining disability to include physical, sensory, neurological, and learning types of disability and so it is not surprising that the documented prevalence of disability in Australia continues to increase as definitions and diagnoses of particular disabilities are enhanced and updated. For example, the recent reclassification and redefinition of Autism and Asperger's Syndrome as Autism Spectrum Disorder (ASD) (American Psychiatric Association, 2013) has led to a subsequent increase in the identification of persons (all ages) with ASD.

According to the Australian Bureau of Statistics (ABS), in 2015, the Australian population (all ages) totalled 23.4 million and of these 4.3 million (18.3%) reported living with a disability. Of the persons with (at least one) disability, 78.5% reported a physical condition (most commonly a back-related problem) and 21.5% reported mental and behavioural disorders. A further 22.1% of the Australian population reported in 2015 a long-term health condition that resulted in no disability leaving 59.5% of the Australian population in 2015 reporting neither disability nor long-term health condition. (Australian Bureau of Statistics, 2016a).

For comparison, in the United States in 2012, the USA population (all ages) totalled 313.9 million and of these 39.7 million (12.6%) reported living with a disability (National Science Foundation, 2017).

The data for Australia was produced by the ABS Survey of Disability, Ageing, and Carers (SDAC) and is aligned with the World Health Organisation's definition of disability such that the ABD survey defines disability as (Australian Bureau of Statistics, 2016a):

> *"…any limitation, restriction or impairment which restricts everyday activities and has lasted, or is likely to last, for at least six months."*

The SDAC defines four levels of disability severity for core activities (Ibid):

- Profound limitation: greatest need for help or who are unable to do an activity
- Severe limitation: sometimes need help and/or have difficulty
- Moderate limitation: need no help but have difficulty
- Mild limitation: need no help and have no difficulty but use aids or have limitations

In 2015 in Australia, 1.4 million of the 4.3 million people with disability had a profound or severe limitation (nearly half of whom were aged over 65 years). The prevalence of disability in the Australian population was slightly higher for females (18.6%) than males (18.0%) with this gender imbalance more pronounced in older age groups. (Ibid).

There were 164,000 people in Australia reported by the 2015 SDAC as having Autism (a 42% increase from 115,400 in 2012) and of these 64.2% have a profound or severe core activity limitation.

Due to changes in how autism is clinically diagnosed since 2013 (American Psychiatric Association, 2013) it is expected that the reported prevalence of Autism in Australia will further increase in future as more Australians are identified with this disorder. There is a significant imbalance in the gender rates for Autism with males having a prevalence rate of 1.1% compared to females with 0.3%.

The SDAC defines six broad disability groups where a group may include only a single disability or include a number of similar disabilities. The six disability groups are (Australian Bureau of Statistics, 2016a):

- Sensory
- Intellectual
- Physical
- Psychosocial
- Head injury, stroke or acquired brain injury
- Other

Just over 50% of the 4.3 million people with disability in Australia in 2015 reported using aids or equipment with 25.9% using communication aids for speaking, reading, writing, hearing, email, or internet activities. Hearing aids were the most common type of communication aid used by 17.7% of people with disability (Ibid).

Within the 2015 resident population in Australia of 23.4 million, there were 15.4 million (65.9%) aged 15 to 64 years (working age population). Of this working age population, 2.2 million (14%) reported a disability of which 538,000 (25.9% with a disability) had profound or severe core activity limitation (3.5% of the total working age population) (Ibid).

For comparison, in 2012 within the resident population in the United States of 313.9 million, there were 195.5 million (62.3%) aged 18 to 64 years. Of this population group, 20.5 million (10.5%) reported a disability (National Science Foundation, 2017). This age group does not include ages 15 to 17 years however the reported disability rate for the age group 15 to 64 years in the United States in 2012 was 13.1%, for the age group 18 to 34 years was 6.0%, and for the age group 5 to 17 years was 5.4% so an exact age grouping of 15 to 64 years for this data is likely to show a lower reported disability rate than for the age group 18 to 64 years.

In 2015 only 53.4% of the working age population with disability were part of the Australian labour force (employed or seeking work) compared to 83.2% of the working age population reporting no disability. The unemployment rate for those with disability was almost double at 10% compared with 5.3% for those without disability. Nearly half (46.6%) of the working age population with disability was not in the labour force compared to 16.8% for those without disability (Australian Bureau of Statistics, 2016a).

Disability Inclusion in Australian Higher Education

In 2015 of the 2.2 million resident population with a disability in Australia, 41% had achieved Year 12 or equivalent education (up from 35.6% in 2012) as compared to 62.8% (up from 59.8% in 2012) for the resident population without disability. Only 17% of the working age population with a disability had completed a Bachelor Degree or above in higher education compared to 30.1% of working age people without disability(Australian Bureau of Statistics, 2016b)

In Australia, people with disabilities other than Autism are 2.3 times more likely, and people without disability are 4.4 times more likely, to have a Bachelor degree or above than people with Autism (Australian Bureau of Statistics, 2016a).The ABS estimates that in May 2016 a total of 3.1m (19.7%) of the 15.7 million working age population in Australia was enrolled in formal study. Of this 1.3 million (43% of those enrolled in study) were enrolled in a course in higher education (Ibid).

According to data from the Department of Education and Training's (DET's) for the first half of 2016 (1 January to 30 June), of the reported 1.25 million students enrolled at some time during this period in higher education 1.15 million (up from 1.12 million) in first half of 2015) were enrolled within the 38 public "Table A" universities (Note that Table A includes the Bachelor Institute of Indigenous Tertiary Education, Darwin, which accounts for only 15 students in this dataset). The total undergraduate enrolment (including Diploma courses and other undergraduate award courses) at Australian public universities in the first half of 2016 was 825,000 with female representation at 55.7% (Department of Education and Training, 2017a).

But of the 1 million plus students engaged in higher education in Australia, what is the reported prevalence rate of disability, i.e., how many students with disability are reported and, more importantly, receiving education provider-based support as students? The National Centre for Student Equity in Higher Education (NCSEHE) has analysed data from DET and reports that the national student with disability (as reported) rate in 2015 was 6.2% (Koshy, 2016).

However this rate must be treated with caution as it has been computed only for one level of course across the Table A public universities. Koshy analysed only the Bachelors Pass course level ignoring all course levels below (including Associate Degree, Advanced Diploma, Diploma, etc.) and all course levels above (including Bachelor's Honours, Bachelor's Graduate Entry, and all postgraduate levels). According to DET data for the first half of 2016, the Bachelor's Pass course level accounts for 708,807 students (61.8% of all levels – undergraduate and postgraduate reported by DET). While this is the most significant level (by student numbers) in Australian higher education the sole use of it eliminates consideration of almost 40% of all higher education students in Table A public universities and almost 45% of all higher education students in Australia (all education providers) (Department of Education and Training, 2017a).

The course levels reported by DET cover Australian Qualifications (AQF) levels 5 through 10 (Australian Qualifications Framework, 2017) whereas Koshy's data on student equity enrolments and ratios, computed from DET data, covers only AQF Level 7 (Bachelor Degree) courses. This of particular relevance to accredited professional undergraduate courses such as for engineering where in Australia they are at AQF Level 8 (Bachelor Honours Degree).

Students with disability data (Koshy, 2016), although limited to AQF 7 (Bachelor Degree) courses at the Table A public universities in Australia shows that at least for over half of all higher education students in Australia the reported rate of students with disability has been increasing year-over-year from 4.4% in 2008 to 6.2% in 2015.

In 2011, the Department of Industry, Innovation, Science, Research, and Tertiary Education (DIISTRE) published a participation rate across all Table A public universities of 4.77% for domestic students with disability higher education in Australia in 2011 with an increase year-over-year of this rate from 4.01% in 2006 to 4.77% in 2011 (Department of Industry Innovation Science Research and Tertiary Education (DIISTRE), 2011).

Consulting firm KPMG performed and analysis of unpublished DET data and determined that students with disability accounted for 5.1% of all students in higher education in 2013 (increasing from 3.7% in 2004) (KPMG, 2015).

How does the reported rate of student disability in Australia compare internationally? Of the 23 million undergraduates students in the United States in 2012 there were almost 2.6 million (11%) students with disability. (National Science Foundation, 2017).

The data for students in the United States also reveals that the reported rate of disability for graduate students was lower than for undergraduate students at 7% and that for both undergraduate and graduate students the likelihood of students with disability enrolling in a science or engineering course was about the same as for students without disability (one in four for undergraduate and one in five for graduate). (Ibid).

Research in the United States to investigate the popular belief that students with ASD were more likely to enrol in STEM courses in higher education was affirmative with the findings that the STEM participation rate was significantly higher for young adults with ASD (34.31%) as compared to the general (Neurotypical or non-ASD) population (22.80%) (Wei, Yu, Shattuck, McCracken, & Blackorby, 2013). This research study also indicated that with increasing early diagnosis of children with ASD that their postsecondary (higher education) enrolment rate may continue to increase.

In United Kingdom higher education, in 2014/15 there were 2.3 million students and 83,000 (3.6%) were reported as students with disability (Taylor, Turnbull, Bleasdale, Francis, & Forsyth, 2016).

Of the public universities in Australia, Deakin University accounted for 45,600 students (4.0%) during the first half of 2016. Deakin's Faculty of Science, Engineering, and Built Environment contains courses that align to four DET broad fields of education: Natural and Physical Sciences, Information Technology, Engineering and Related Technologies, and Architecture and Building. In the first half of 2016, the Table A public universities in Australia had a total 284,021 students enrolled collectively in these four fields of education (Department of Education and Training, 2017a).

An analysis of internal enrolment data shows that on 1st October 2017, the total enrolment (all course levels) in the Faculty of Science, Engineering and Built Environment (SEBE) was over 7,600 students. Combining the DET 2016 data and the Deakin 2017 data gives an indicatory (only) result of approximately 2.7% of students across these four fields of education across Australia were enrolled in SEBE courses at Deakin (with an obvious caution on the inexactness of this figure).

Of the 7,600 students enrolled in SEBE courses at Deakin, as of 1 October 2017 there were 198 students (2.6%) registered with Deakin's centralised Disability Resource Centre for formal support and assistance with their studies as a student with disability. This reported rate of students with disability in SEBE (for 2017) is significantly lower than the national rate of 6.2% (for 2016) reported by Koshy - at less than half.

As is the default policy with most education providers, at Deakin it is up to the student to seek assistance with support services and nominate themselves as a student with disability. One contributing factor causing lower-than-expected student with disability rates (as measured by prevalence rates of disability in the general population) in Australia is likely to be the perceived social stigma of being identified as 'disabled' and especially if the disability is one of mental health (Fuller et al., 2009; Kimball, Wells, Ostiguy, Manly, & Lauterbach, 2016; Simpson & Ferguson, 2014).

The significantly lower reporting rate within SEBE courses at Deakin indicates that students are either unaware, poorly informed, or reluctant to seek assistance for their disability from the centralised resource centre. This is a common problem in higher education where the onus is on the student to identify themselves as a student with disability in order to receive support and appropriate adjustments to assist their learning (Borland & James, 1999; Fossey, Chaffey, et al., 2017).

According to the NCSEHE a contributing factor for lower participation by students in disability support resources offered by education providers is a lack of awareness of the availability of these resources by students and how their specific needs could be met (Cunninghame, Costello, & Trinidad, 2016).

A common problem in researching disability, not only in students but in the general population, is the plethora of definitions – especially for data collection and reporting purposes. This issue exists not only across various institutions, national and internationally, but also between government departments (Gale & Parker, 2013).

An example of this disparity in data and statistics for disability is national rate of reported disability in Australia for those aged 15 to 64 years (working age population). In 2011 DIISTRE published a reference value of 8% disability rate for this population group (Department of Industry Innovation Science Research and Tertiary Education (DIISTRE), 2011). This rate is significantly lower than the ABS published rate for this population group in 2015 of 14% (Australian Bureau of Statistics, 2016a).

This problem is also evident when seeking to compare student disability data as recorded and reported within education providers and as recorded and reported nationally and internationally. For example, at Deakin University a total of 13 distinct disability groups are used to record student disabilities. One of the significant groups accounting for 27% of all student with disability registrations at SEBE has a very broad title of “Medical Condition” and so it prevents direct comparison to other grouping schemes – such as the six broad disability groups used in the SDAC.

From the SEBE data however the dominant disability group is “Mental Health or Psychiatric” with a prevalence rate of over 40% of registered students with disability. This rate appears to correspond with a rate for mental health disability of almost 40% of students with a reported disability at another Australian public university, Latrobe University (Simpson & Ferguson, 2014). Simpson & Ferguson also report that the number of students reporting a mental health disability at Latrobe has doubled over recent years.

Disability Inclusion in Australian Engineering Education

In Australia, in the first half of 2016, there were over 1.2 million enrolled students in higher education and of these over 900,000 (72.1%) were Australian citizens. Of this total student population over 98,000 were enrolled in engineering and related technologies courses (Department of Education and Training, 2017a).

Engineering and related technologies courses (all levels) accounted for 96,286 students (8.4%) of the 1.15 million students enrolled across the 38 Table A public universities in the first half of 2016, up 4.2% from the first half of 2015 (Ibid).

Of the 7,600 students enrolled in SEBE courses at Deakin, 1,700 (22.4%) were enrolled in Engineering and Related Technologies courses and of these 1,700 students only 26 (1.5%) were registered with Deakin’s Disability Resource centre as a student with disability.

There were almost 550 postgraduate degree-by-coursework students within these totals of which only 1 student (0.2%) was registered as a student with disability and this accounts for the significantly lower disability reporting rate for this field. For undergraduate students there were 25 (2.1%) registered as a student with disability; still lower than the overall Faculty reporting rate (2.6%).

The data readily available and presented here on disability inclusion in engineering education at one Australian University only offers a slight insight into the current situation – both within this institution and nationally. What is apparent is that a gap exists in research on disability inclusion not only in engineering education but more broadly across all STEM courses in higher education and across high education in general at a national level and international level (Järkestig Berggren, Rowan, Bergbäck, & Blomberg, 2016). Like many existing studies what is uniquely presented here is limited to a single university when looking at disability inclusion in engineering education.

What may also exist as a potential barrier to increased disability inclusion in Australian engineering education is the degree of difficulty and length of most accredited undergraduate engineering courses. Aside from the University of Melbourne’s Bologna-modelled “3+2 year” Bachelor/Master course, in Australia accredited undergraduate engineering courses are 4 year’s full time duration and at AQF Level 8 (Bachelor’s Honours).

An opportunity may exist to revise existing or develop new pipeline engineering courses, typically 2 years duration at AQF Level 5 or 6, so as to be more attractive and more accommodating of students with disability. In the United States, students with disability are more likely to enrol in courses of 2 years duration (National Science Foundation, 2017). Also in the United States students who engage in research in the first 2 years of college are more likely to persist with STEM courses (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013). If a causal link exists here for engagement and retention then it may support the development of more inclusive pipeline engineering courses for Australian higher education.

Improving Disability Inclusion

Since 2008 a number of fields of education have lost enrolment share even though the overall higher education student enrolment in Australia continues to increase year-over-year. (Norton & Cakitaki, 2016). Of concern to many is the continual decline in enrolment share of STEM courses including engineering and information technology.

Although participation rates in STEM courses, as compared to non-STEM courses, in higher education is greater for students with ASD the overall participation rates of students with ASD, and of students with disability, remains relatively low in Australia. As such the underserved disability population, and especially those with ASD as a disability, exist as an underutilised source of skilled labour for the Australian economy.

This opportunity exists not only in Australia but also other countries including the United States which similarly has a growing shortage of STEM-skills in the work force (Thurston, Shuman, Middendorf, & Johnson, 2017; Wei et al., 2013). In the United States a 2012 report by the President's Council of Advisors on Science and Technology predicted a deficit of 1 million STEM graduates over the following decade (Graham et al., 2013). In Australia this shortfall and potential for enabling additional STEM student sources was recognised by the 2008 Bradley Review of Australian Higher Education – as highlighted by Larkin et al. (Larkin, Nihill, & Devlin, 2014).

And contrary to popular belief (i.e., assuming persons with disability are most likely to be employed in occupations involved light or sedentary work) in Australia the largest proportion of employed persons with disability (almost 20%) are working in professional occupations (Athanasou, 2014).

Through the use of Universal Design for Learning (UDL), the ability exists to provide an enhanced environment for students in higher education where individual student needs can be better accommodated so as to enable greater access, greater engagement and retention, and greater course and graduate outcomes for a greater proportion of the working age population. Existing research, although limited, indicates that a combination of reasonable adjustments and support can be effective in supporting students with disability in higher education (Fossey, Chaffey, et al., 2017).

UDL promised the ability to individualise adjustments for students so as to enable knowledge to be gained, knowledge to be demonstrated, and interaction with teachers and peer students (Burgstahler, 2015). An example of this is the use of UDL in engineering education to reduce language-related barriers for students with learning disabilities (Variawa & McCahan, 2010).

But UDL in STEM higher education presents many as-yet unsolved issues as identified by Moon et al. (Moon, Todd, Morton, & Ivey, 2012) including:

- Major gaps exist in research on how STEM can accommodate students with disability
- Lack of research in the application of UDL to higher education

- How to make “team-based” (such as project-based learning) and “hands-on” learning (such as laboratory-based learning tasks) more inclusive
- How to make work-integrated learning, especially course-mandated work integrated learning more inclusive

The traditional academic, as associated with non-constructivist objectivist teaching methods, is under increasing threat primarily due to increasing demands for greater authenticity in learning and assessment tasks (Cavenett, 2017). With increasing awareness of types and prevalence of disability in the general population an increasing need exists for improved for disability inclusion in education at all levels including higher education.

An in-depth study of students at a small Australian University reports that students with disability feel that there is a lack of understanding by academics of the pressures they are under and their grades did not reflect their true abilities (Ryan, 2007). This adds to the complexity involved – of increasing authenticity in learning and assessment while simultaneously improving inclusion.

Adequately supporting students with disability in higher education requires individualised (reasonable) adjustments to the learning environment, learning tasks, and assessment and with this there exists a need to further explore more effective and less complex processes to enable this (Brett, 2016; Fossey et al., 2015).

However some of these adjustments are occurring “naturally” as more education providers shift to online and blended learning methods exploiting contemporary communication and information technologies. With almost 26% of the Australian population using aids for communication, the underlying adjustment technologies and learning methods either already exist, e.g., electronic forms of study materials that are compatible with various types of communication aids, or can be reasonably enhanced to provide the necessary individual adjustment. Online learning, for example, does and can provide for inclusion of students with severe or profound psychosocial or intellectual disability (Boyd, 2014).

Improving disability inclusion in higher education requires the need for academics to include principles of universal design in the development and provision of course curricula and learning experiences (Järkestig Berggren et al., 2016). Effective academic-student relationships demand skill, knowledge, and capability on behalf of the academic. The academic must be capable of coping with being a person of trust for the student: the current observation is that students often reveal their disability directly to teachers with whom they have an existing relationship rather than to an education provider’s centralised disability support service (Fossey et al., 2015).

And the adjustment needed is not only with the learning and assessment, as controlled by the academic staff, but also adjustment by universities to enable and support the academic staff for developing and implementing more inclusive practices (Smith, 2010). This may include appropriate training and development of academic staff so they are capable of designing and enabling reasonable adjustments for individual students with disability (Asghar, Sladeczek, Mercier, & Beaudoin, 2017; Fossey, Bigby, et al., 2017).

Conclusion

Data on the prevalence of disability within higher education students in Australia, and internationally, indicates that students with disability are underrepresented and there exists a need to improve disability inclusion in higher education. However there also is evidence that student disability is underreported, in Australia, and internationally due to a number of inhibiting factors including student reluctance to identify themselves as having a disability and an associated perceived social stigma.

Gaps in the research on the actual prevalence rates of student disability in higher education exist and this coupled with the variance in definitions of disability and how it is recorded and reported makes it difficult to perform any detailed comparative analysis of national and international student disability data. Assessment of available data and research supports a conclusion that actual prevalence rates of student disability in higher education in Australia significantly higher than reported. And that students with disability are reluctant to seek, or unaware of the availability and value of, disability support from within higher education providers and also that there exists significant barriers to higher education access for a significant proportion of the population with disability.

In Australia and other countries including the United States there is a sustained trend of a decline in enrolments in STEM courses in higher education coupled with an increasing shortage of STEM-skills in the work force. Increased disability inclusion in higher education offers a way to tap into an underutilised source of STEM students to boost the supply of STEM-skilled graduates.

To increase disability inclusion in higher education a multiple stakeholder supportive environment will need to provide reasonable adjustment on an individual student basis to outcomes-based effective (and authentic) learning and assessment to be possible for all students (including students with disability).

There exists in Australia, and internationally, an underutilised source of STEM students that can boost the supply of STEM-skilled graduates to work forces, such as Australia's, experiencing an increasing shortage of STEM-skilled professionals. To significantly increase disability inclusion in higher education will require significant change involving multiple stakeholders.

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Grounded by values: An emergent engineering practice

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SESSION C4: The role and impact of engineers and the engineering profession in the wider community

CONTEXT A transformational change in engineering education culture is required to address ongoing issues such as declining interest and a lack of diversity in the student cohorts and profession. This change must go beyond transforming educational pedagogies; organisational cultural change is necessary to shape perceptions about engineering and engineering in society. The creation of the Engineering Practice Academy at Swinburne University of Technology provides the opportunity to intentionally construct a culture guided by a set of espoused values that can be used to define and guide the emergent culture, and inform decisions made in the development of the Engineering Practice Academy.

PURPOSE This paper describes the development process of co-constructing espoused values within the Engineering Practice Academy.

APPROACH Espoused values were co-constructed by project stakeholders through a facilitated workshop. The workshops included individual tasks, reflections and sharing, and collective discussion used to facilitate the construction of the values.

RESULTS The five espoused values co-constructed by project stakeholders were: collaboration with empathy, honesty through transparency, equity and diversity, sustainability through practice and, excellence – individually and collectively. The espoused values are being used in all aspects of the Academy’s creation such as evaluating and selecting potential initiatives, generating an ethical partnership policy to guide the selection of external partners and creating a culture to attract and support a diverse staff and student cohort.

CONCLUSION Values-based decision making has been shown to empower individuals from all levels of an organisation to make decisions as well as being useful in the recruitment and retention of staff and students. Values present a novel resource for informing collaboration between Universities, industries, and community.

KEYWORDS Values integrated practice, Engineering Practice, Being and becoming an engineer.

Introduction

The Bachelor of Engineering Practice (Honours) degree at Swinburne University of Technology, Melbourne, Australia was designed and developed to equip future engineers with the capabilities and attributes crucial for a twenty-first-century engineering career. The development of the program challenged the Engineering Practice Academy (Academy) at Swinburne to re-conceptualise engineering education. The Academy provides the social, cultural, political, technological, economic and ecological contexts in which the Bachelor degree operates within and delivers engineering education entirely through industry and service learning projects and other professional development activities. The Academy operates as an engineering practice being both a professional service provider and a higher education institution.

This paper reports on the process undertaken by the Academy to construct a practice culture guided by a set of espoused values. Values are details that assist a practice in moving towards a desired future state by directing the emergent now and the course of daily work processes (Dolan & Garcia, 2002). Values can, therefore, in the case of the Academy be used to define and guide a new culture, and inform decisions made in regards to the development of the Academy processes. Culture is the inescapable by-product of repeated human interaction. Schein (1983, p. 14) defines organisational culture as:

> *the pattern of basic assumptions that a given group has invented, discovered, or developed in learning to cope with its problems of external adaptation and internal integration*

While practice cultures are often left to grow organically and develop of their own accord as a result of how members of the practice think and interact, a practice culture can also be intentionally constructed or invented, to some extent, through conscious effort (Schein, 2010). The intentional development of a practice's culture is most likely to occur, at the very beginning of a practices life, and as such, reflect the values and behaviours of the founding group. Schein (2010) model for organisational culture presents three levels of culture thus being: artefacts, espoused beliefs and values and, underlying assumptions. Of these three, the most important, regarding the influence of a practices culture are the underlying assumptions about the "problems of external adaptation and internal integration" (Schein, 2010, p.18) that each member of a practice holds. Underlying assumptions are however unique to each member of the team and can be quite divergent, especially in the early days of the development of culture.

In the case of the Academy, five exposed values were co-constructed by eight Academy stakeholders (university decision-makers, Academy employees and, engineering educators) in a facilitated workshop. Schein's (2010) model of organisational culture structured the workshop activities and the established espoused values were used to guide the creation of the practices strategic objectives. The Academy intentionally created the espoused values early in the development of the Academy because the timing was believed to be crucial in ensuring that the adopted values underpinned the emerging culture and vision of the Academy. Furthermore, it was anticipated that early adoption of the values would empower the Academy staff to make decisions that aligned with the direction of the underlying strategy of the Academy.

Influence of values and culture in education

The Academy and its associated Bachelor degree were co-created with stakeholders which included industry representatives, university decision-makers, Academy employees and, engineering educators. Academy stakeholders were challenged to be responsive to the existing social, historical, technical and economic barriers that prohibit individuals engaging in engineering education. Furthermore, Academy stakeholders were asked to recognise systemic limitations that current and future engineering students encounter because of the current culture within engineering education.

For Australia to be a leader in engineering, a change in the culture of engineering and engineering education is needed, from one that is mostly exclusionary to one that is both inclusive and diverse. The idea of culture and cultural change has entered the mainstream of the discourse on engineering education only recently (Godfrey, 2009). Investigations into aspects of engineering education culture have included Cech's (2013) study that showed engineering students' commitments to and concerns about public welfare declines over the course of their training. This phenomenon was described as a culture of disengagement, and an ideology of depoliticisation presents the:

> *belief that engineering work can and should be disconnected from 'social' and 'political' concerns because such considerations may bias otherwise 'pure' engineering practice (Cech, 2013, p.7).*

The perception of engineering being a profession whereby the social and the technical cannot and should not be separated in practice and especially in engineering education has begun to occur (see, Pawley, 2009; Riley, 2008) thus changing the landscape of engineering education programs. Furthermore, engineering education programs are beginning to facilitate the development of the self with self-efficacy in engineering another aspect of educating future engineers examined recently (see, Mamaril, Usher, Li, Economy &, Kennedy, 2016). In the context of engineering education, self-efficacy concerns individual's confidence and knowledge about their aptitude to perform engineering tasks (Bandura, 1982; Ponton, Edmister, Ukeiley, & Seiner, 2001). For students in an academic environment, self-efficacy and self-perception influence individual's cognitive engagement in studies, working with others in a team and their persistence in understanding and applying engineering knowledge in practice (Pajares & Miller, 1994).

Engineering education provides a nexus of opportunities and experiences in which students become to identify themselves as an engineer. Furthermore, the rhetoric of engineering presented by a university influences an individual interpretation of being an engineer and engineering as a profession. The:

> *activities, historically salient understandings about engineers and engineering, and routines for recognition as engineers - all of which frame how students navigate educational opportunities and, for some, become engineers thought to belong (Tonso, 2014, p.277).*

Changes in academic environments, curriculum strategies, and technology approaches are an ongoing process in the development of engineering education. It is a university's responsibility to prepare graduates to be industry ready whereby they are required to solve problems that address social and environmental impacts, be self-responsive and behave professionally, develop consumer relations and understand business acumen. Besides curriculum changes, cultural change in engineering education is a crucial aspect because an individuals interpretation and identity as an engineer are "held between person and campus culture" (Tonso, 2006, p. 301). The culture of the university in which a person studies engineering and the activities and rituals the person is exposed to concerning engineering as a profession informs their identity as an engineer. Meaning, universities develop students standing as an engineer and the values, underlying beliefs and assumptions they hold in regards to engineering as a profession (Godfrey, 2009). However, exposure to a universities engineering degree is not the only avenue in which an individuals identity of as engineer manifests, as identity as an engineer is also an outcome of sociocultural and socio-temporal contexts both within and external to the degree being undertaken by a student. However, this paper is explicitly addressing how the Academy, one engineering university program, constructed espoused values to acknowledge the responsibility the Academy has to students identifying as being-and-becoming an engineer.

The activities and rituals in conjunction with the technical skills delivered by the Academy will inform students identity as an engineer. Furthermore, the shared-values the Academy holds as a working and learning practice will influence students' perception of belonging within the field of engineering. Shared-values are the manifestation of deep-seated patterns of team beliefs, supportive morals and social/peer responsibilities (Schein, 2010). Behaviour is an enacted aspect of culture (Godfrey, 2009) and behavioural values are performed through both direct and indirect verbal and non-verbal forms of communication. For example, the behaviour of staff working in an academic environment can be perceived either directly or indirectly by a student cohort as being a reflection of the value system of the university. Furthermore, the language used by staff in regards to the representation of who an engineer is, verbally communicates to students who constitute being an engineer in the eyes of the university program.

The culture of a practice can be positioned as a mechanism to "shape who is included and who is excluded" (Faulkner, 2009, p. 5) and typically it is the dominant cultural group who determines who is accepted. In the engineering workforce, men outnumber women by a factor of over two for those in the top pay-bracket ($104 k + per year), and conversely, women are over-represented in the lowest pay bracket (Office of the Chief Scientist, 2016). The disparity between woman and men connected to the discipline of engineering is associated with high-school to university pathways into engineering education being considered biased against women and is compounded by declining numbers of women undertaking traditional prerequisite subjects including advanced mathematics and physics in high school (Australian Council of Engineering Deans Inc, 2017). Unconscious bias against girls in STEM emerges in primary school (Sarkar, Tytler, & Palmer, 2014) also contributes to the lack of gender diversity within the discipline of engineering.

The lack of diversity in the discipline of engineering extends beyond gender. Diversity can be considered as a measure of heterogeneity across a given population; whether that be gender, sexuality, culture, or socio-economic status (Hunt, Layton, & Prince, 2015). Diversity can be encouraged by promoting equality of opportunities. Within the engineering discipline, this needs to operate across the educational system and subsequently in the workplace. Within the educational system, young people from a low socio-economic status backgrounds are less likely to study STEM disciplines (Lamb, Jackson, Walstab, & Huo, 2015), while Aboriginal and Torres Strait Islander participation in engineering degrees has limited enrollments (Department of Education and Training, 2016). When studying engineering at university, lesbian, gay, and bisexual students often engage in tactics to navigate a predominantly heterosexual culture, which places additional academic and emotional labour on these students (Cech & Waidzunas, 2011).

From a practice perspective, benefits from increased diversity can include improvements in innovation (Østergaard, Timmermans, & Kristinsson, 2011), financial performance, ability to attract and retain staff, and organisational reputation (Workplace Gender Equality Agency, 2016). Culture and the shared-values of a practice should:

> *recognise and affirm woman's as well as men's competence and commitment, so that all, not just the numerically dominant group, find the work enjoyable and personally fulfilling in an inclusive and supportive workplace (Ayre, Mills &, Gill, 2013, pp. 230-231).*

The Academy as a new practice that traverses both a professional service provider and a higher education institution acknowledged its responsibility to address systemic limitations that current and future engineering students encounter in entering an engineering degree and continuing to becoming a practicing engineer. The development of the Academy's espoused values aim to empower Academy staff to make decisions that align with the espoused values and culture of the Academy as a practice.

Project scope

The culture of a practice emerges over time and is influenced by the individuals who were formative in the development of the practice. The developmental phase of a team is critical as it is the time when the agenda, values, expectations and shared direction of the practice are negotiated and assigned. The development of shared direction is a “blend of what the leader brings and what the macro context of the group affords as it grows” (Schein, 2010, p. 71). Meaning, the development of a practice and its culture is an outcome of the leader's assumptions of and for the practice and its members in conjunction with the construction of shared assumptions between team members.

In the case of the Academy, the development of an espoused culture and values were positioned and treated as being emergent. The Academy openly acknowledged that the advocated culture of the Academy would develop over time and as the practice evolved from three individuals to fifteen, the supported culture would continue to emerge as new members engaged with the existing practice culture and challenged it. Academy members openly discussed the evolution of its practice culture within structured team meetings and project management workshops. The development of the practice culture external to the formal culture and values building workshop discussed in this paper was necessary to ensure Academy members were empowered to employ a values-based decision-making system. As the Academy continues to develop the values-based decision-making system will continue to be researched; however, this paper discusses how and why the Academy established the initial espoused values that are being applied within a values-based decision-making system.

Understanding culture as being established across three levels being (1) artifacts, (2) espoused values, and (3) tacit assumptions grant the opportunity to recognise that culture is both individual and collective (Schein, 2010). The correlation between overt behaviours and espoused values of a practice is complicated; this is because espoused values, tacit assumptions and the immediate now can causes divergence from what a group wishes the ideal outcome to be (Schein, 2010). The urgent now can present situations, which because of time or resources, constrains the idealistic approach that aligns with the practices espoused values. In the case of the Academy mitigation of espoused values, tacit assumptions and the immediate now was brokered through various processes, which were themselves emergent and reactive processes. This paper does not address the processes that the Academy employed to address how espoused values, tacit assumptions and the immediate now was brokered. However, it is important to note that the Academy team were aware that the development of culture is impacted by the circumstances of the immediate now.

Creation of the values: Method

The development of the Academy's espoused values was structured around Schein’s understanding of culture. Members of the Academy participated in a total of four workshops designed to develop, expand and refine the creation of the values. This paper discusses explicitly workshop number three which was designed to unpack and expand on the five espoused values established in workshop number two. Workshop number three was titled *an open discussion on values* and focused on refining the selection of values and generating a shared understanding of each value.

Reflection-in-action as a theory and method was used to position the development of the espoused values and informed the design of the workshop. Reflection-in-action acknowledges that individuals are “agents” (Schön, 1995, p.328) within a group and it is through an individual’s agency they shape and are shaped by the social system of the team. Through this understanding, the Academy members who participated in the workshop would both inform and be informed by their peer’s participation.

The workshop was structured to allow for tasks to be completed individually, followed by reflection and sharing than collective discussion. The outcomes of the workshop were synthesised by the workshop facilitators and shared back to the participants after the completion of the workshop which provided the opportunity for participants to reflect upon the findings and implement them in their daily practice. The implementation and reflection of ideas or insights is an essential element of a reflection-in-action process. Insights are acquired from research is application and inform the next iterations of activities thus creating a cycle of reflection and implementation.

The workshop was positioned as an open discussion on values with values being expressed as how we want to approach everything we do and what values we will embed in everything we do. The workshop comprised of four activities with activity one being a visioning task where all members of the Academy were asked to individually reflect on and then collectively share their motivations for joining the Academy and what they hoped to achieve as being a member of the Academy. This task was designed to open up a conversation around intrinsic motivations and their connection to values and goals. Activity two presented the values statements of four different organisations that spanned the Australian public, private and not-for-profit sector. This task was designed to demonstrate the variants in the articulation of values. Participants in activity three were then required to individually generate five potential values for the Academy expressing what the values mean for them. Participants then paired and discussed their values to create shared understanding and document the common elements. Two pairs then came together and repeated the process until the whole team was back together, see Figure 1 for the outcome of this task. Following this task, participants collectively prioritized the values being of low importance to high. Through this process, participants started to group interdependent values. At the completion of the workshop, the participants had generated five working espoused values and had begun to produce a shared understanding of each value, see Figure 2. The five value sets created within the workshop were:

- Collaboration with empathy
- Honesty through transparency
- Equity and diversity
- Sustainability through practice
- Excellence – individually and collectively

Engineering
Practice
Academy
Workshop three: An open discussion on values
Generation and explanation of potential Academy values

PARTNERSHIP:
Achieve more together

CONSTRUCTIVE:
Say yes, positive attitude and approach

EVIDENCE-BASED:
Grounding our solutions and our operations in the best available evidence.

HUMILITY:
Letting our work and our efforts speak for themselves

POSITIVE:
Approaching our work and our interactions with positivity

FEARLESSNESS:
Not letting our egos stop us from attempting the impossible.

RESPECT:
For others
For people and culture
For the land

ADVENTURE:
Agile and ready for a challenge

SAFETY:
Of others and the community

ENERGY:
Throw yourself into things and encourage others to do so

CONSCIOUS:
Being mindful of our impact on each other, our clients and the whole world.

OPEN-MINDEDNESS:
I will always consider alternate points of view

SERVICE:
To our team
To our clients
To the community

COMMUNITY:
Create a sense of support, friendship, care and fun

SELFLESS:
Other above yourself

INTEGRITY:
As people and as a practice

SERVICE OF AGENCY:
people are free to make their own choices

CONTINUOUS LEARNING:
Everything is a learning opportunity, failure is an opportunity to learn.

AUTHENTICITY
Be real to yourself and others

Figure 1: Outcome of workshop activity three: Generation and shared understanding of potential Engineering Practice Academy values.

Engineering
Practice
Academy
Workshop three: *An open discussion on values*

COLLABORATION WITH EMPATHY
- We no better together and we enjoy it
- Work together with others
- Communicate frequently and clearly
- Share success/failure
- Enjoy working with others
- Seek new opportunities
- Work together for mutual benefit creating shared value
- Consider others points of view
- Respect others circumstances recognising you may no know what they know.
- Willingness to think of another's circumstance

HONESTY THROUGH TRANSPARENCY
- Showing the why , how and what in all we do.
- Releasing our work into the world to assist and inspire others

EQUITY AND DIVERSITY
- Everyone has equal value
- Work sensitively with people from all backgrounds
- Understand others may have different perspectives
- Celebrate differences
- Of thought
- Of people
- Of solutions

SUSTAINABILITY THROUGH PRACTICE
- To our team
- To our clients
- To the community
- Striving to leave things as they are or better
- Social, environmental and economic

EXCELLENCE – INDIVIDUALLY AND COLLECTIVELY
- Be the best we can be, individually and collectively
- Striving to be good people and good engineers who care.

Figure 2: Outcome of workshop activity four: The espoused Engineering Practice Academy values and the shared understanding of the values.

Results: Acting and reflecting on values

The creation of a practice's culture is emergent, and changes as the practice grows and develops new knowledge and perspective. The espoused values generated by the Academy was positioned as working values because they will inevitably be modified as the culture of the Academy develops and the values continue to be implemented into decision-making processes. At the completion of the workshop and once the outcomes were distributed the participants came back together and reflected on the generated values and the evolution of the values from workshop one to the result of workshop three. Within this meeting, the team acknowledged that equity and diversity should become diversity and inclusion. The process of generating shared values requires participants to be advocates for the organisation and to recognise the value of different opinions. It was through a process of reflection and collaboration that Academy members began to negotiate their perspectives and begin to form shared values for the Academy.

The espoused values co-created by the Academy are being used in all aspects of the Academy creation such as evaluating and selecting potential initiatives, generating an ethical partnership policy to guide the selection of external partners and creating a culture to attract and support a diverse staff and student cohort. Since the creation of the espoused values Academy representatives have participated in a vision setting workshop where participants created the strategic objectives to achieve each of the value elements. Workshops were then held with all Academy members to align and priorities their projects to contribute to these objectives in a manner that maximized the impact across all generated vision elements. Throughout this process, the espoused values were used as a lens to inform the decision-making processes.

Discussion

An explicit statement of the culture of the Academy expressed through the five espoused values described in this paper provided at least four tangible benefits to the operation of the practice as both a professional services provider and a higher education institution. At a strategic level, the values provide a test against which potential initiatives can be judged and thus provide clear direction to the practice. Operationally, the values are a powerful tool to guide decision-making; decisions that are inconsistent with the values are not desirable and are thus avoided, and other options considered. Within the context of the practice reported in this paper, the values have already been effectively used to guide decision-making around the types of industry partners that the Academy chooses to engage with, and indeed, to guide decisions on the level of engagement with specific companies.

Values-based decision-making systems, when used effectively, can be implemented across practices to devolve decision-making down through hierarchies by empowering individuals, not just managers, to make decisions, yet ensuring that such decisions are not detrimental to the practice as a whole. Further, clear values are an effective tool for recruitment and retention of, in this context, both academic and professional staff, and students. Explicitly-stated values attract individuals that share those values and increases their commitment to the practice when they experience their beliefs and assumptions reflected in their work (Sullivan, Sullivan, & Buffton, 2002).

Employing values as a framework to construct decision making is not uncommon in engineering practice, as Catalano (2012, p. 118) states “engineering is a value-laden profession with a strong ethical foundation”. The true test of the values created by the Academy will lie in the communication, implementation, and ownership of the values by staff, students and supporters of Academy who were not present in the construction of the values.

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Creating shared value: An industry project framework

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SESSION C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

CONTEXT

Engineers have a responsibility to serve the communities in which they work and create solutions to the challenges that society faces in the 21st century, while maintaining the economic viability of the organisations to which they belong.

Current engineering education approaches often fall short of equipping graduates with the required skills to navigate the tensions between social and ecological sustainability and creating financial value.

An emerging concept in business literature, *creating shared value*, offers a framework to create value for society while simultaneously creating financial value for companies.

PURPOSE

This paper explores how the concept of *creating shared value* may be transferred from business literature to the engineering education context, as a way to equip graduates with the skills suited to the unknowns of future engineering practise.

APPROACH

This paper reflects on what shared value means to students, universities, industry and communities in the context of integrating industry and service learning projects as a mode of course delivery.

RESULTS

The creation of the new Bachelor of Engineering Practice at Swinburne University of Technology and the resulting industry project framework are used as an example to explore how the concept of creating shared value may be implemented.

CONCLUSIONS

The concept of *creating shared value* is a mechanism that can be used within engineering education to equip graduates with skills required for the unknowns of the future while simultaneously providing opportunities for universities as institutions to positive social impact for the communities in which they are located.

KEYWORDS Industry projects, shared value

Introduction

Society is facing global challenges associated with depleting natural resources, climate change, increasing populations along with technological advances that have both the potential to push society towards or away from sustainability (Broman & Robèrt, 2017). The engineers of the 21st century will need to alter their skillsets and approaches to respond to these challenges and in turn engineering education must adapt to create graduates ready to work in this changing environment.

Engineers, perhaps more so than most other professionals, have the potential to create large scale technological solutions to create positive social (Baillie, 2014; Fitzpatrick, 2016) and ecological impact and to shift society towards sustainability (Fitzpatrick, 2016). It is the responsibility of engineers to fulfil this potential. This responsibility is recognised in the preamble for the Engineers Australia (EA), Australia's peak engineering body, Code of Ethics states:

> "As engineering practitioners, we use our knowledge and skills for the benefit of the community to create engineering solutions for a sustainable future. In doing so, we strive to serve the community ahead of other personal or sectional interests." (Engineers Australia, 2017)

Engineers are expected to be both technical professionals and leaders within their companies. Engineers must then be equipped with technical and problem solving sills ready to tackle complex global challenges in addition to business acumen and leadership skills (National Academy of Engineering, 2005).

There are many studies within the literature calling for changes to engineering education approaches to respond to meet the needs of a changing society (Beanland & Hadgraft, 2014; King, (2008)). There are many different models, curriculum, pedagogies and frameworks being trailed and adopted by the engineering education community in response to this. Educational programs such as the EWB Challenge, an Australasian design program (Engineers Without Borders Australia, 2017), along with courses on engineering and social justice (Baillie, 2014) and the rise of dedicated humanitarian engineering education programs in Australia and New Zealand are all providing opportunities for students to explore the role of engineers in creating social impact and sustainability. Courses focusing on business, enterprise and management skills are also being made available to engineering students.

Within industry the need of companies to be financially sustainable and create a profit is often in direct competition with social and ecological agendas and the pressure from society to contribute to these agendas (Porter & Kramer, 2006, 2011). This tension between social and ecological impact and profit making is in part perpetuated by outdated notions of corporate social responsibility (CSR) (Porter & Kramer, 2006, 2011). Within the business literature *creating shared value* (CSV) is emerging as an alternative to CSR that creates social impact while simultaneously creating financial value (Porter & Kramer, 2006, 2011). The concept of shared value is still emerging but is already being adopted by companies. There is a need to provide companies with guidance on how to implement the concept (Dembek, Singh, & Bhakoo, 2016) in addition to a need for business schools to adopt better curriculum to better prepare graduates to create shared value (Porter & Kramer, 2006, 2011).

Engineering education often falls short of equipping graduates with the required social and economic skills to contribute to moving society towards sustainability (Fitzpatrick, 2016). There is a need to focus more on both social and economic aspects within engineering education (Fitzpatrick, 2016). Furthermore, as business schools must change approaches to allow graduates to navigate the tension between social impact and profit making so does engineering education. This paper explores how the concept of *creating shared value* (CSV), may be transferred from business literature to the engineering education context, as a way to prepare engineering graduates to be able to not just navigate the tensions between social impact and economic profit but to avoid the tension in the first place.

This paper does not attempt to critique alternative approaches, nor does it attempt to compare the incorporation of CSV to other approaches within the engineering education literature. This paper simply introduces the concept and provides suggestions of how the concept of creating shared value may be incorporated into engineering education using the creation of a new Bachelor of Engineering Practice at Swinburne University of Technology (Swinburne) as an example to stimulate discussion and debate.

The tension between social impact and economic profit

There is a prevailing view within the general public that companies make profits at the expense of the communities in which they work, that companies will prioritise profits over doing social good (Porter & Kramer, 2011). *Corporate social responsibility* (CSR) programs within companies have emerged over many decades in response to this criticism by the general public. The definition of CSR varies widely within the literature, as do the frameworks, and in some cases lack of frameworks, with which companies create CSR policies. In general, however CSR programs focus on creating positive environmental and social impacts beyond the companies legal obligations (Bosch-Badia, Montlor-Serrats, & Tarrazon, 2013).

As CSR programs extend beyond a company's legal obligations and core business they are typically considered to be a financial burden by organisations (Bosch-Badia et al., 2013) and incompatible with making a profit (Porter & Kramer, 2011). Despite the financial cost of CSR to a company, societal pressure on companies to be seen doing social good has resulted in the continuing prioritisation of CSR activities (Porter & Kramer, 2006, 2011). What results is a tension within companies between maximising profits and creating positive social and ecological impact (Porter & Kramer, 2006, 2011). This tension is one that engineering professionals must learn to navigate throughout their careers.

Profit making and social impact however are not mutually exclusive. There is a need for new mindsets and organisational approaches to reframe how companies view and action the creation of social and ecological impact (Australian Centre for Corporate Social Responsibility, 2014). Examples of these new approaches can be seen in the rise of social enterprises (Reilly, 2016) and B-corporations (B Lab, 2017). Engineering education in turn needs to adopt new curriculum and pedagogies to equip graduates with the skills required to approach business and the creation of social and ecological impact in new ways.

Creating shared value – the concept

Porter and Kramer introduced the concept of *creating shared value* (CSV) in Harvard Business Review articles in 2006 and 2011 as an alternative to corporate social responsibility (CSR) that negates the tension between making a profit and creating social impact.

> "Shared value can be defined as policies and operating practices that enhance competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates." - (Porter & Kramer, 2011)

Some would argue that *creating shared value* is simply an optimal definition of *corporate social responsibility.* For example, the Australian Centre for Corporate Social Responsibility (ACCSR) define CSR as:

> "Organisational practices that address the impacts of an organisation on business, society and the environment or seek to create positive social value through core business." - (Australian Centre for Corporate Social Responsibility, 2014)

Very few CSR programs live up to this ideal however and are instead activities unrelated to core business that allow for good deed publicity opportunities (Bosch-Badia et al., 2013). The

ACCSR 10-year review of the state of CSR in Australia and New Zealand noted that CSR progress was unsatisfactory and called for systemic change in CSR practices in order to address deep-rooted social, environmental and economic challenges (Australian Centre for Corporate Social Responsibility, 2014). In this paper, we recognise the overlaps between CSR and CSV but have chosen to focus on the concept of CSV, as defined by Porter and Kramer above, as it cuts through the different definitions and outdated approaches to CSR giving room to inspire new thinking and action.

To paraphrase Porter and Kramer (2006 and 2011) corporate social responsibility programs are often kept separate from the business strategy and in a lot of cases are either managed by marketing departments or independent units such as foundations within a company. The concept of shared value brings the focus on social impact in from the fringes of an organisation to the core business strategy. The high-level CVS framework that Porter and Kramer (2006 and 2011) present revolves around identifying the points of intersection between society and the company or organisation’s operations. Corporate social agendas are then created to address value chain social impacts and social dimensions of competitive context at these intersections.

We propose that CSV frameworks could be incorporated into engineering education curriculum to equip graduates with skills for their careers in addition to embedding CSV principles into university operational and research strategies to show leadership and generate new knowledge on the creation of shared value.

The social responsibility of universities

Universities are not immune from the pressures of society to create social impact. As public institutions universities have a responsibility to serve the communities in which they are located (Nørgård & Bengtsen, 2016). This service is reflected in the strategic plans of universities across Australia and New Zealand. For example, Swinburne University of Technology’s 2025 strategic framework positions Swinburne as “a world class university creating social and economic impact through science, technology and innovation”.

Universities intersect with society and have opportunities to create shared value with society through the education of students, the development of staff and the knowledge created through research. These same opportunities exist when the focus narrows from a whole institutional view to a focus on a single faculty, such as engineering, or a single discipline within a faculty, such as engineering education.

Creating shared value through engineering education

At Swinburne University of Technology an opportunity has arisen to rethink engineering education and experiment with new approaches through the creation of the Engineering Practice Academy (the Academy), launching in 2018, and its associated Bachelor of Engineering Practice (Honours) (BEPH). The Academy is one of many initiatives that operationalise Swinburne’s mission to create social and economic impact. Throughout the creation of the Academy consideration has been given to how the Academy’s operations might create shared value with the local community of Melbourne where the Academy is located, communities within Victoria and Australia more broadly, the Australian professional engineering sector and finally the international engineering education community of which Academy staff are members.

The Academy is being established as a simulated consulting firm within Swinburne. Students will join the Academy as associates enrolled in the BEPH. The BEPH is being co-created with industry and will be delivered entirely through real-world projects with industry and community partner organisations. Curriculum will be delivered with a just-in-time approach and students capability to apply the concepts within the curriculum tracked through micro-credentials. Students will move through four intensive six-week units a year, with each unit focusing on one of four curriculum pillars; social impact, emerging technology, research and development and entrepreneurship. In addition to the projects conducted within the four units, 15% of student's workload will be dedicated to service learning projects working alongside Academy staff on long-term projects within the community.

In the early stages of establishing the Academy a strategic planning process was undertaken, identifying the contribution that the Academy could make to social issues affecting the communities in which the Academy intersects. The strategic planning process identified five vision elements through which the Academy could have impact:

1. Develop engineers suited for the unknowns of future engineering practise
2. Embody and advocate sustainability
3. Celebrate being and becoming professionals
4. Embrace diversity and inclusion
5. Re-imagine and transform engineering education

The design of the Academy's programs, policies and procedures in all areas including; operations and infrastructure, people and culture, services and engagement with community and clients, are at the time of writing this paper being aligned to the five vision elements and mapped to show how they will contribute to the achievement of desired outcomes and thus create shared value under each of the vision elements.

Industry and service learning projects framework

The structure of the BEPH allows for natural intersections with both the Australian engineering sector and the boarder community through student-led projects with industry and community based organisations. The BEPH includes two types of student-led projects, 1) industry based projects within the six-week intensive units and 2) long-term service learning projects with community based organisations.

Service-learning projects have been used internationally with great success to embed a sense of social responsibly and equip students with global citizenship skillsets (Bielefeldt, Paterson, & Swan, 2010; Pritchard & Tsang, 2000). Service-learning projects place students within communities where they work on a project that benefits the community in which they are embedded. Service-learning projects through their very nature have the potential to create shared value with communities. Service learning projects conducted in isolation to industry projects however have the potential to perpetuate the view that social impact is achieved through CSR activities that are separate to core business.

In the Academy students will also work on real-world projects identified by industry partners in addition to service learning projects. These industry projects are also viewed as an opportunity to create shared value. Industry projects have the potential to create shared value;

- For **students** by providing opportunities to build skills, gain exposure to professional working environments and build their professional networks;
- For **industry partners** to crowdsource new ideas and innovative solutions for projects they identify in addition to opportunities to identify up-and-coming talent within the next generation of engineers;
- For **society** by acting as transformative platforms through which industry partners in collaboration with Academy students and staff can identify opportunities to increase the social and ecological value of the industry partner's core business. Participating in student projects allows industry partners to explore these opportunities in a low-risk manner, without the need to commit time or financial resources up-front.

Establishing real-world projects and partnerships with industry and community based partner organisations however is not enough to ensure that shared value is created. At the time of writing this paper the Academy is in the process of creating an industry projects framework complete with tools to assist academic staff to design student projects to explicitly create shared value, prioritise projects that will contribute to achieving the Academy and broader Swinburne University of Technology strategic plans, effectively facilitate students to deliver projects and evaluate the social impact they create.

Conclusions

Engineers of the future must be equipped with skills to address global social and ecological challenges. They must be able to serve society and create financial value to the companies in which they operate. Outdated notions of corporate social responsibility coupled with societal pressure on companies to create social impact outside of their legal obligations are creating tensions between social impact and profit making. Current engineering education approaches are not adequately preparing graduates to navigate this tension.

The emerging concept within the business literature of *creating shared value* provides a framework for companies to identify opportunities to create social impact while simultaneously creating economic value for the company. The concept of *creating shared value* is a mechanism that can be used within engineering education to equip graduates with skills required for the unknowns of the future while simultaneously providing opportunities for universities as institutions to positive social impact for the communities in which they are located.

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Effective use of Zoom technology and instructional videos to improve engagement and success of distance students in Engineering

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CONTEXT Distance engineering education is a familiar and well-accepted mode of study in Australia, especially for regional areas, due to improvements in technology and convenience of learning opportunities. Many students choose distance mode over face-to-face because of flexibility around work and family commitments. But still, there are a lot of challenges to maintain student engagement and to make learning by distance as effective as on-campus studies. Moreover, most of the distance students choose to study and want to engage with academics outside standard working hours which challenges work-life balance. Online support tools such as Zoom allow students and academics to connect through virtual tutorials from any convenient location, which is an effective use of technology to improve student engagement and their success rate while minimising the inconvenience of after-hours commitments for academics.

PURPOSE The aim is to study the effectiveness of using Zoom technology to offer evening tutorial sessions to improve the success of students studying foundation engineering units by distance mode at a regional university, while maintaining a manageable workload for academics.

APPROACH A course Moodle site gives information about the learning behaviors of students. For example, data can be collected on how many students watched a lecture or the most frequently watched parts of lectures. In this study, student engagement with the course was measured by closely observing the number and types of posts to the Q&A Forum on the Moodle site for the years 2016 and 2017 and the number of students attending Zoom virtual tutorials when introduced in 2017.

RESULTS Data collected from the Moodle site over the 2016 and 2017 course offerings showed levels of engagement were maintained with the learning resources (Q&A Forum in 2016 and additionally the Zoom virtual tutorials in 2017). Also, a similar response rate was recorded for the course evaluation questionnaire but satisfaction scores improved in many areas. The introduction of Zoom virtual tutorials resulted in higher student satisfaction and a reduction in instructor workload of approximately 25%.

CONCLUSIONS By offering online Zoom tutoring sessions, the number of questions and answers posted on the Moodle has reduced significantly and reduced the workload of academics. This has been achieved without reducing the engagement levels of students or altering the grade distribution.

KEYWORDS Online teaching support, Zoom virtual tutorial; student satisfaction.

Introduction

Distance education originated to fulfill the demand for education by those who would not be able to participate in face to face courses. It is suitable for those courses which do not require physical attendance during the learning process. Distance education incorporates a variety of ways to enable students to progress along the pathway of their studies. CQUniversity (CQU) offers two pathways in its engineering degrees. One is with Co-op experience (the dual award program Bachelor of Engineering/ Diploma of Professional Practice (Engineering)) and another is the distance education program (Jorgensen & Howard, 2005a). CQU employs new technologies to provide state of the art education to enrolled students. At this moment, CQUniversity is also well regarded in Australia as the nation's most inclusive and engaged university due to offering distance education and as well as having campuses in many regional areas. Approximately 27% of the enrolled CQU engineering students take their courses as a distance mode due to the flexibility of technology (Mandal, 2015).

Emerging technologies allow instructors and students as well as student-student connection in a real-time and or time delayed alliance. Several techniques were used to deliver the distance program for a period of time (Cohen & Ellis, 2001). First generation distance education basically depends on print based education (Kaufman, 1989; Nipper, 1989). Whereas second generation distance study evolved to print and broadcasting system (Peters, 2002). Third generation distance education heavily dependent on web-based tools, such as web conferencing which enables student – teacher more equitable communication (Bates, 2005). Software companies are creating user-friendly tools that are incorporated in learning and teaching in an educational institution. The latest addition is called "Zoom", full details of this application are available online: https://www.zoom.us

From Term 1 2017, CQU enabled "Zoom" as the virtual live classroom for distance students' educational purposes. Zoom is a web based tool which enables collaboration between individuals and groups through video conferencing, video and audio calling, instant and persistent messaging, and file sharing. Zoom was adopted primarily as a replacement Virtual Live Classroom (VLC), but offers a range collaboration opportunities – within and beyond CQU.

Background

Implementation of technologies for distance studies is dependent on individual comfort levels, monetary resources and visionary leadership (Beldarrain, 2006). The educational institution must be aware of the influence and outcome of the technologies that have been used for facilitating learning pathways. It's also equally important to train the educators to familiarise them with a new technology including its possible flaws during the process. To adopt a new technology, CQU follows the seven principles of good learning and teaching practice provided by (Chickering & Gamson, 1987). Irrespective of delivery method, technology should:

- Encourage contact between students and faculty.
- Develop reciprocity and cooperation among students.
- Use active learning techniques.
- Give prompt feedback.
- Emphasise time on task.

- Communicate high expectations.
- Respect diverse talents and ways of learning.

CQU encourages all academic staff to undertake these approaches for achieving better learning outcomes. The online distance pedagogical journey can be integrated by using emerging technologies such as “Zoom” by applying these seven principles.

Now distance learners are interested in connecting with peers and receiving prompt feedback from their instructors and want to study interactively. This is more applicable to those specialised subjects which need to be explained step by step, for example tutoring about mastering software applications.

Course History

This paper illustrates the gain in learning effectiveness using “Zoom” technology for the particular specialised subject called “Drafting for Engineer’s” which is offered in distance mode as part of an Associate Degree in Engineering. Two consecutive year’s data has been analysed to determine correlations between using the new technology “Zoom” and effects on student satisfaction and feedback. In addition, the numbers of relevant technical questions asked through the Moodle site have been considered in this study to assess the qualitative relevancy of the “Zoom” tool.

Table 1: Summary of the number of students enrolled, student satisfaction scores and a number of questions posted on the Moodle Q&A Forum for two consecutive years.

Drafting for Engineers (ENAG11009)						
Item / Year	Enrolled Students	Responses	Response Rate	Overall satisfaction score out of 5	Number of Questions asked through Moodle site	Types of resources
2016 Term 1	45	18	40%	3.2	279	Recorded video and Q&A forum
2017 Term 1	34	18	53%	4.5	129	Recorded video plus first time used “Zoom” as an interactive tool for live tutorial

Student Satisfaction Scoring System and its Application

The teaching and learning environment is greatly influenced by a student evaluation and feedback process (Sayem & Rasul, 2015). Frequent student evaluation and adding their feedback into course improvement will make the learning process more informative and interactive. CQU uses a five-scale rating system to evaluate course performance. The corporate target of average satisfaction of a course is 4.0 out of 5.0. In addition, at least 50% or more student feedback has been considered acceptable in the evaluation process. Finally, CQU also has an attrition target of less than 30% failures in a particular course. Updated resources along with innovative learning and teaching methods incorporated with the latest technology have been used to fulfill the CQU corporate targets. The key points of the changes are to: 1) Improve the student learning process, 2) Increase positive satisfaction in the student learning journey, and 3) Reduce the student dropout rate. The following section summarises the different strategies that have been considered to meet the corporate requirements.

Teaching Interventions

Table 2 summarise the various teaching interventions that are responding to student feedback for the years 2016 and 2017.

Table 2: Summary of the various teaching interventions responding to student feedback for the years 2016 and 2017.

2016 HT 1 : Drafting for Engineers (ENAG11009)			
Student feedback	Source	Recommendation	Action taken
Online tutorials were of benefit to students	Have your say survey	Increase the number of Online tutorials to enable students to ask questions and be shown the answer	Casual staff conducted fourteen, two hour online tutorials during the term
Too many folio exercises	Have your say survey	Review the Pass/Fail requirement of the folio exercises and possibly allow students to choose how many folio activities they do; however specific help on Assignment tasks will not be given as the assignments are meant to be done solely by each student without help from staff or other students	The number or folio activities were reviewed and reduced slightly in line with the hours students are expected to spend on a 6CP unit
Course videos were good and showed step by step instructions	Have your say survey	Review the current online videos and add more where needed	Completely reviewed all videos prior to the term and employed casual staff to add/fix over ten, 30min videos
Assessment items were returned late	Have your say survey	Staff will monitor and ensure the timely return of feedback to students for future offerings	Coordinator helped teaching staff with marking

Table 3: Learning resource score and forum discussion statistics for 2016 and 2017

	2016 Term 1	**2017 Term 1**
Enrolled students	45	34
Course evaluations	18	18
Student engagement	36% participation in Q&A forum	35% participation in Zoom virtual tutorials
Types of learning resources	Q&A Forum and 2 one-hour online tutorial sessions	Q&A Forum and 14 one-hour Zoom virtual tutorials
HD grades (%)	70%	75%
Student satisfaction of learning resources as a numerical scale from 1 (low) to 5 (high)	3.1	4.0
Q&A Forum posts per student	1.9	1.0
Instructor time to deliver learning resources	Number of Q&A Forum replies (148) multiplied by nominal time to reply (10 minutes) plus 2 hours of online tutorial session. 26 hours	Number of Q&A Forum replies (38) multiplied by nominal time to reply (10 minutes) plus 14 hours of online tutorial session. 20 hours

Results and Discussion

Quality assurance of learning and teaching processes is very important for any educational institution to sustain its progress. For academics, it's also important to deliver high-quality learning methods (Dekkers, Howard, Adams, & Martin, 2014). Modern technology has provided vital assistance to achieve the required standard of quality of learning tools. From Table 1, student satisfaction rates indicate that tutorial sessions with "Zoom" technology have influenced the achievement of a higher satisfaction score (4.5). Student feedback in the year 2017 said that Online "Zoom" tutorial sessions provided good interactive help. Another important key parameter is the number of questions posted in the Q&A Forum over 2016 and 2017. In 2016, the same course was offered without "Zoom" and the number of questions asked per student was 1.9, whereas this was approximately half in 2017. In 2017, due to tutorial sessions being offered by "Zoom the instructor workload reduced by approximately 25%. The introduction of Zoom also resulted in a marginal increase in the percentage of HD grades awarded. As assessments were not significantly changed over this period, this is anecdotal evidence that Zoom tutorials may also allow students to obtain deeper learning.

In addition, at the time of "Zoom" tutorial sessions, students showed their interest about the "Zoom" collaborative tool for providing effective impacts to achieve the goals of the course. Therefore, we can consider that there has been a positive impact of "Zoom" technology in the learning process. Further analysis can be done to determine the impact of "Zoom" by organising a one to one survey based on a questionnaire on the students' "Zoom" experience. The author will recommend this for the next stage of the learning development.

Instructor Observation

The author observes from solicited and unsolicited feedback about the “Zoom” collaborative tool that it creates better student satisfaction. Students enjoy tutorial sessions and asked for extra sessions due to the effectiveness of “Zoom” technology. In particular, for the “Drafting for Engineers” course, “Zoom” was especially helpful to allow students to see live command of various tools and their applications through the course teacher. Course teachers also enjoy seeing the benefits of the “Zoom” tool, especially for distance courses. Overall, students and course teachers were both happy to use “Zoom” collaborative for the first time in their “Drafting for Engineers” course.

Conclusion

The implications of introducing Zoom virtual tutorials was examined with respect to student satisfaction, student engagement and instructor workload in a core drafting course within the Associate Degree in Engineering at CQUniversity. It was found that by using “Zoom”, the learning process is more interactive, which creates positive student satisfaction and better experiences in their learning journey. The innovative approach of “Zoom” enhances positive learning outcomes for diverse groups of students as well as encouraging higher education in remote areas while potentially reducing workloads for instructors.

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Integrating Social Impact throughout an Engineering Curriculum

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SESSION Integrating Humanitarianism in Engineering Education

CONTEXT The potential that engineering offers of making a positive impact on society motivates many students, yet most university courses only appeal explicitly to this motivation through add-on global experience or service-learning programs. Furthermore, there is an increasing body of research showing that such Social Impact programs lead to improved student outcomes, especially in the development of the professional skill-sets and mind-sets required in the 21st century engineering workforce.

At Swinburne University of Technology, social impact is being integrated and embedded in a new curriculum, co-designed with industry partners, grounded in education research, and built around work-oriented pedagogies including project-based learning. Projects will be aligned with 4 Pillars: Emerging Technologies, Entrepreneurship, research & Development (research in lowercase to indicate the emphasis on Development), and Social Impact. This paper reports on the process of incorporating Social Impact into this new curriculum.

PURPOSE How can Social Impact be integrated throughout an engineering curriculum?

APPROACH Building from an industry co-design process of identifying and unpacking the suite of skills required to succeed and flourish as an engineering graduate, the next stage is developing the curriculum and learning experiences that will enable students to acquire these skills. Within the context of Social Impact, this process involves consulting the education research literature on developing these skills, input from prospective Social Impact project partners, comparison with related project-based and service-learning programs, and then further consultation and validation with industry stakeholders.

RESULTS Several milestones have been reached in developing the Social Impact curriculum pillar. The key aspects distinguishing it from the other pillars have been identified as *empathising and communicating with people from diverse backgrounds*. A system of micro-credentials will be used as a framework for developing students' skills, and some of these, such as *human-centred design*, *thinking globally*, and *embracing diversity*, have been mapped to Social Impact. At the time of writing, a Deep Dive curriculum workshop had just been held with industry stakeholders – the outcomes and analysis will be presented at the conference, along with an update on the curriculum development process.

CONCLUSIONS By incorporating lessons learned from other programs around the world, evidence-based teaching strategies from the research literature, and ongoing consultation with prospective project partners and industry stakeholders, Swinburne University of Technology is in the process of developing a world-class new initiative to integrate Social Impact throughout the engineering curriculum.

KEYWORDS curriculum design, social impact, service-learning

Introduction

Swinburne University of Technology (SUT) is developing an innovative practice-based engineering undergraduate degree, with a curriculum co-designed with industry (Cook, Mann, & Daniel, 2017). Rather than the traditional focus on technical content, this new *Bachelor of Engineering Practice (Honours)* degree will enable graduates to develop the professional skill-sets and mind-sets required in the 21st century engineering workforce. This new project-centric curriculum will have projects aligned to 4 Pillars: Emerging Technologies, Entrepreneurship, research & Development, and Social Impact. The ongoing process of developing a curriculum framework for this last Pillar, Social Impact, is the subject of this paper.

Context

Growth of service-learning and social impact in tertiary education

Service-learning is a recent and growing development in university education. For example, the first research publications only started coming out in the 1990s (e.g. Markus, Howard, and King (1993), but since then multiple journals have been dedicated to this burgeoning area. The *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship* issued its first Volume in 2006, and the *Journal of Service-Learning in Higher Education* followed suit in 2012.

In engineering, this trend towards addressing social impact can be seen in the rise in recent years of humanitarian engineering education. For example, Engineers without Borders Australia has been running curricular and extra-curricular programs for undergraduate students in this space for more than a decade. Some universities offer humanitarian engineering education research projects or degree specialisations (Amadei & Sandekian, 2010; n.a., 2017a), and now for the first time, the AAEE conference is hosting a session on "integrating humanitarianism in engineering education".

Addressing social impact is an important trend in engineering education that is being centrally incorporated in the new co-designed curriculum at SUT.

Co-designing a new engineering curriculum with industry

At SUT, the process of co-designing a new curriculum with industry, aligned to university and Engineers Australia requirements, together with input from student focus groups, is well underway. It will be summarised briefly here, as it is has been described in detail elsewhere (Cook et al., 2017).

Its structure has so far entailed two broad stages: *stakeholder consultation* and *consensus building*, adapted from the *Design your Discipline* process (Dowling & Hadgraft, 2013). The industry stakeholder consultation process involved three ideas workshops with more than 60 individuals representing more than 50 diverse engineering employers, who were asked to brainstorm and discuss emerging industry trends, the skills required of future graduates, and more.

Those inputs were analysed and distilled into a draft curriculum framework, successive iterations of which were the subject of two further curriculum development workshops. This *consensus building* stage involved a total of 21 participants from 18 different organisations giving feedback and input into revising the draft curriculum. At the time of writing, four 'deep dive' workshops are being held to plumb the four curriculum pillars one-by-one in detail with industry representatives. The analysis and outcomes of the Social Impact deep dive will be presented at the AAEE Conference in December.

The draft curriculum of the *Bachelor of Engineering Practice (Honours)* degree is summarised below in Figure 1. It consists of three domains of people, self, and work, complemented by the 'fundamentals'. Each of the domains of people, self, and work, is divided into three sub-domains. Each of these sub-domains in turn subsumes a number of underlying skills. For example, **Communication** has been unpacked to include: *listening*, *questioning*, *adaptive communication style*, *persuasion & pitching*, *presentation skills*, *networking*, and *writing*. Similarly, **Management** includes *project management, risk management, time management, people management & team building, feasibility & prioritising,* and *budgeting.*

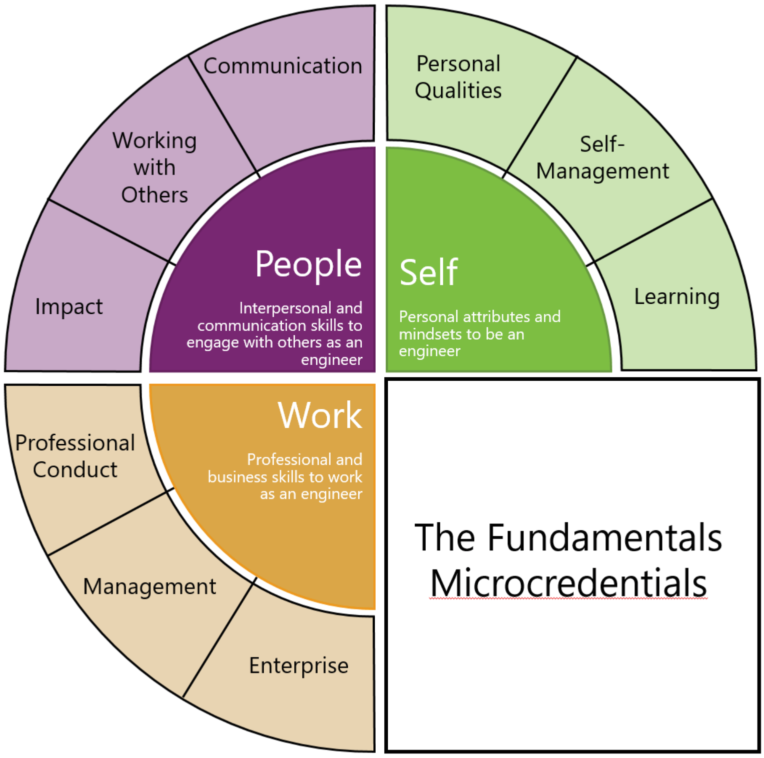

Figure 1: The domains and sub-domains of the draft curriculum

Developing the Social Impact pillar

Inputs and interactions

Apart from input from industry stakeholders, and potentially others such as regulatory or government bodies, the initial and ongoing development of a curriculum and assessment framework for the Social Impact pillar involves a number of inputs and interactions. This includes input from similar programs, feedback loops with industry partners and other ongoing monitoring and evaluation, and engaging with the relevant research literature (see Figure 2). These inputs have been described in detail previously (Daniel & Mann, 2017), and so are only summarised briefly here.

Many service-learning programs in engineering exist at other universities (Bielefeldt et al., 2013). EPICS, at Purdue University, having started in 1995 is perhaps the best known of these, involving inter-disciplinary student teams earning academic credit solving technology-based problems for local community organisations (Oakes, Coyle, & Jamieson, 2000). The *Service-Learning Integrated throughout the College of Engineering (SLICE)* program at the University of Massachusetts-Lowell has the goal of integrating service-learning into every semester of their engineering degree and so will offer an important comparison point for our own program (Duffy, Barrington, West, Heredia, & Barry, 2011; n.a., 2017b).

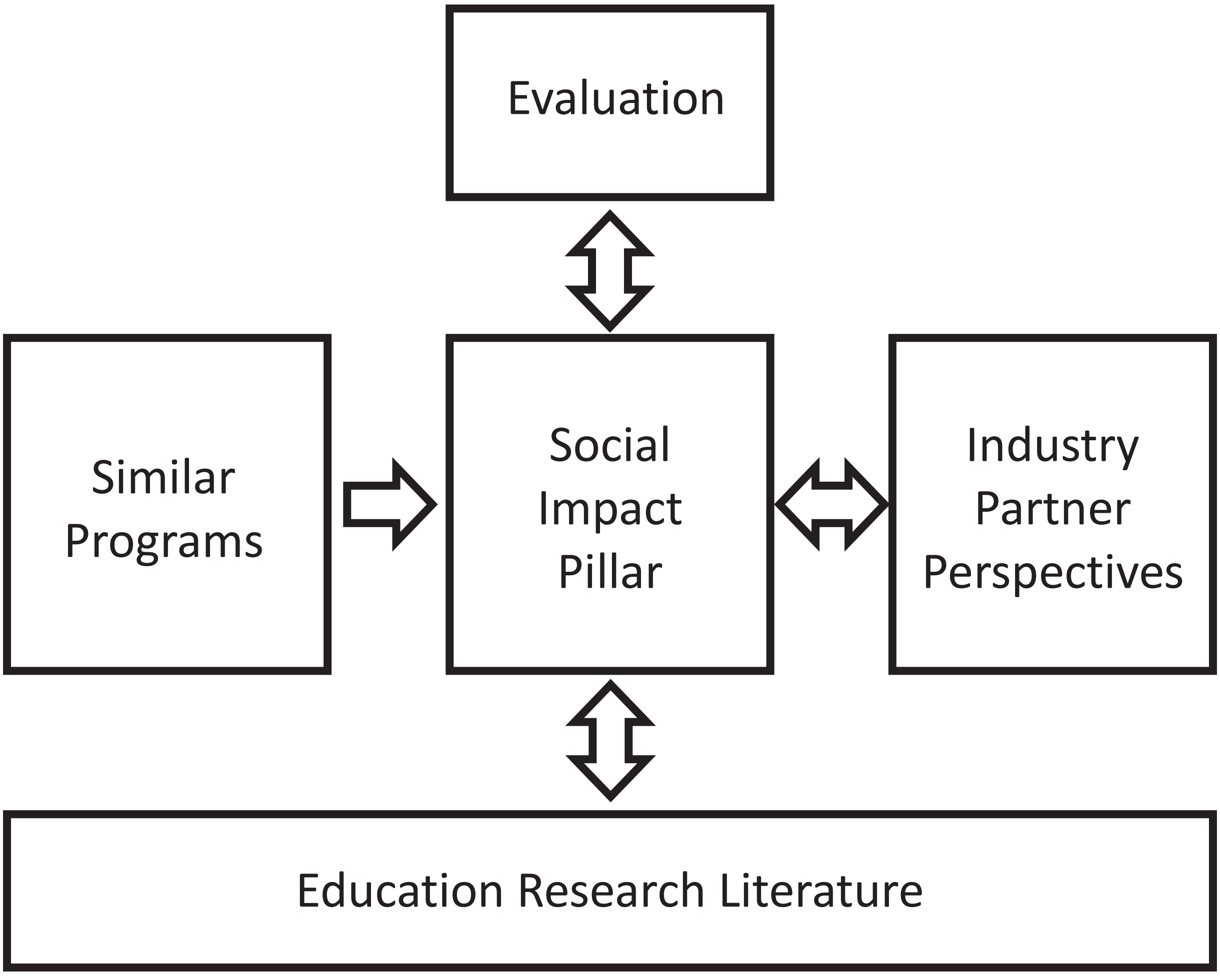

Figure 2: Inputs and interactions informing the Social Impact Pillar

Working successfully on Social Impact projects will require the development of a number of associated skills, such as engaging community members, human-centred design, working cross-culturally, and more. Many research papers have investigated different teaching strategies to nurture these skills, or developed resources that could be useful for teaching them. For example, Gilbert, Held, Ellzey, Bailey, and Young (2014) reviewed the literature on teaching community engagement skills, whereas Mazzurco and Jesiek (2017) identified five best-practice principles for community engagement - a resource both students and teachers can use in developing skills in this area. In a previous paper (Daniel & Mann, 2017), we reviewed this literature in more detail.

Ongoing monitoring and evaluation of this new program will be key to ensuring the best outcomes. Apart from more typical project-based assessment, there will be regular debriefs with project clients, industry mentors, and students themselves. For Social Impact in particular, there are a number of relevant validated survey instruments, such as those developed to measure attitudes towards sustainability (Hess, Brownell, House, & Dale, 2015), or towards community service (Shiarella, McCarthy, & Tucker, 2000), that will be adapted to evaluate our program.

The Social Impact pillar in the degree framework

Students in the new degree program at SUT will join a functioning practice, the Engineering Practice Academy, on Day 1. Each year of the degree, the student experience will be centred around four 6-week ‘sprints’. Each sprint, students will work in small groups on a project aligned to one of 4 Pillars: Social Impact, Emerging Technologies, research & Development, and Entrepreneurship (Figure 3). Although these projects represent the bulk of the workload, students will also participate in professional development experiences as well as working on a longer-term service learning project.

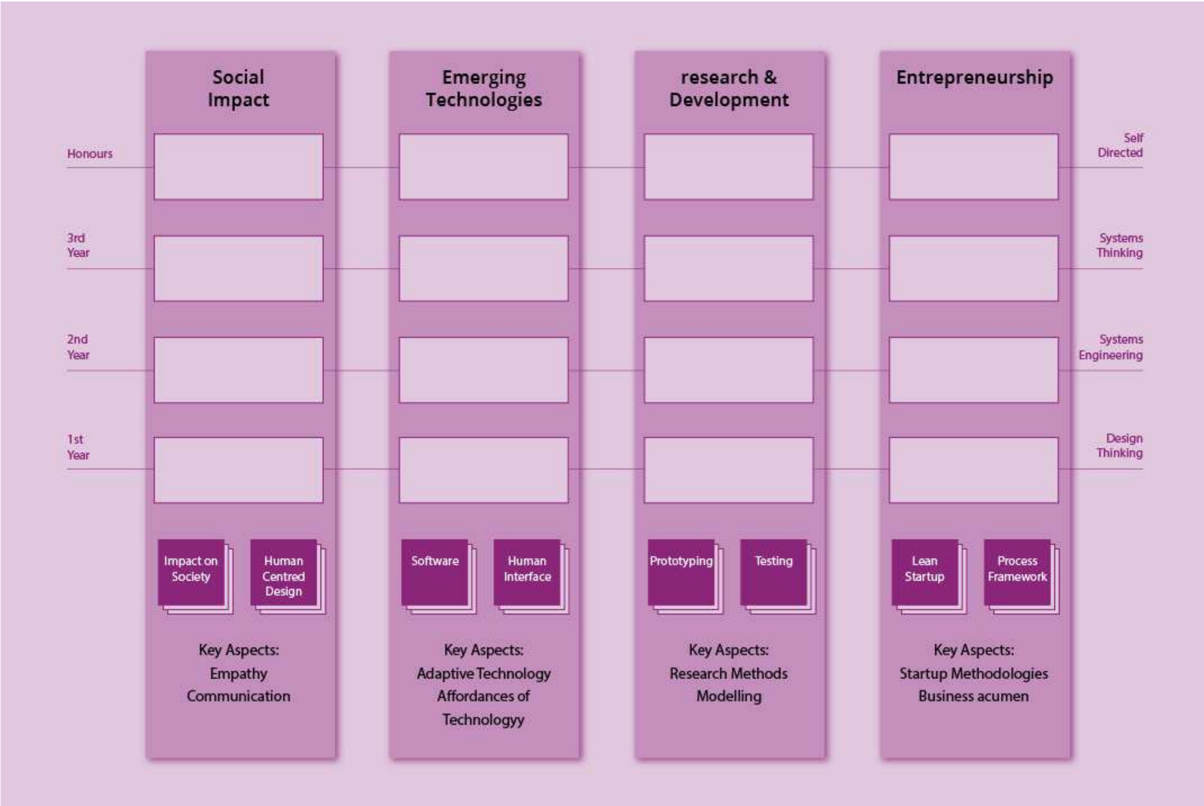

Figure 3: The degree framework of four curriculum pillars

Projects in the different pillars will be distinguished by different key aspects, as indicated at the bottom of Figure 3. The key aspects of the Social Impact pillar are *empathy* and *communication*. Empathy is a central component of human-centred design. Social Impact projects will focus on developing students’ ability to empathise with people from a different background from their own. The other key aspect of Social Impact projects will be developing students’ communication skills in diverse contexts. For example, it could be that in a Social Impact project, students will develop and practice the skills to communicate effectively and empathise with members of a rural community to identify a design opportunity, communicate with their teammates in developing their ideas and designs, and then be able to empathise with the perspective of a philanthropic board to so communicate their proposal convincingly enough to win a funding grant.

In the workplace, the ability to communicate and empathise underpin the concepts of psychological safety and collective intelligence in teams, which in turn are key determinants of team effectiveness (n.a., n.d.; Woolley, Chabris, Pentland, Hashmi, & Malone, 2010).

Service-learning versus the Social Impact project

Although each year all students will complete a 6-week social impact team project, they’ll also spend about 10% of their time working on an Academy-wide service learning project. Of course, the service learning project is intended to have a social impact, so the question arises, how is it different to the project within the Social Impact pillar?

There are several key differences. The intended outcome of the Social Impact project is that students develop particular skills, especially regarding their ability to empathise and communicate with people from a different background to their own. It is a contained, short-term project that will be a central component of each students' performance review, and will effectively involve the student teams conducting R&D for the project client. Conversely, the service-learning project will be on a time-scale of years rather than weeks, and rather than being focused on student learning and assessment, will instead be about producing a tangible outcome for the client.

The first Social Impact pillar project that the initial 'pathfinder' cohort in 2018 will work on is the EWB Challenge. The EWB Challenge is an established humanitarian engineering design program for first-year students, now in its tenth year (Jolly, Crosthwaite, & Kavanagh, 2010). It involves student teams from around Australia and overseas developing design solutions for community-based partner organisations in developing countries. The best student designs are shared with the community partner each year. That is, the student teams research and develop ideas and prototypes to address issues faced by the partner organisations and their communities, and so the EWB Challenge is the archetypal Social Impact project.

Micro-credentials underpinning the Social Impact pillar

One task in developing the new degree program has been reconciling the curriculum co-designed with industry (Figure 1) with the university framework of two semesters split into four sprints (Figure 3). To facilitate this process, we physically printed each curriculum point on a separate slip of paper and then had a robust and interactive discussion to map them to the different pillars. A snapshot of this process is shown below in Figure 4.

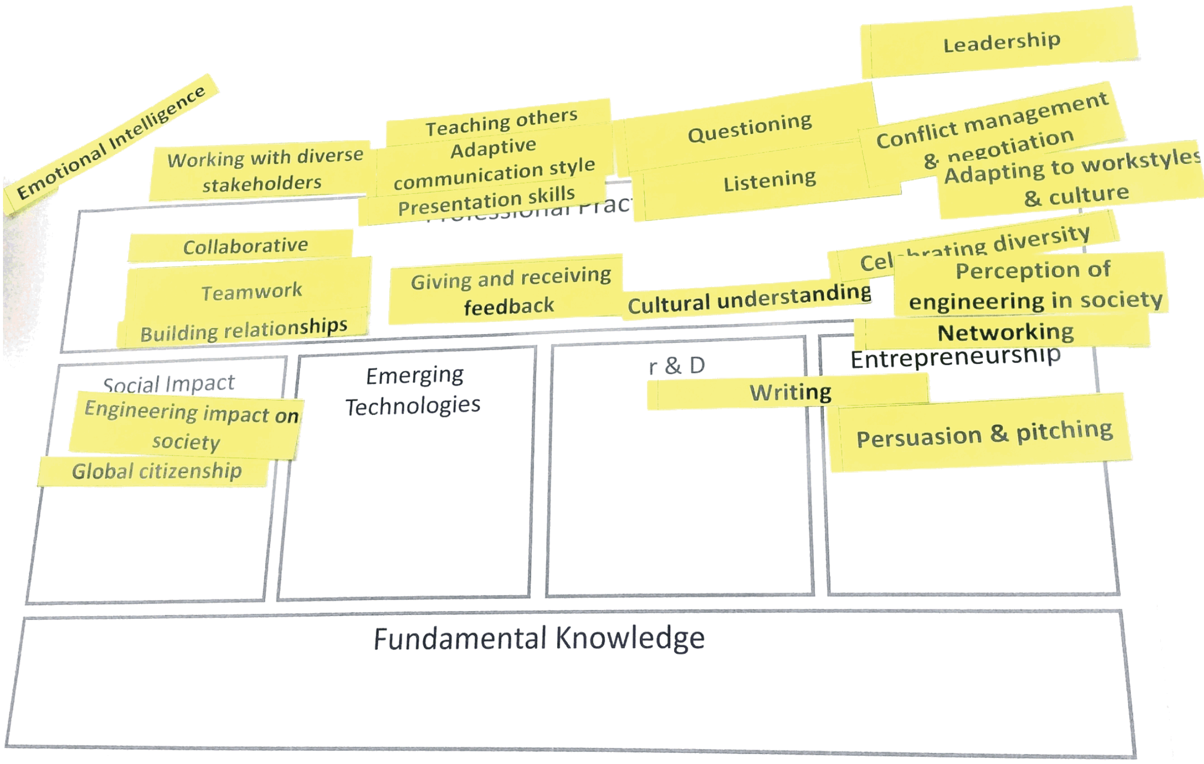

Figure 4: The process of mapping the *People* curriculum domain to the different Pillars

The outcome of this process was matching the following six points to the Social Impact pillar: *Global Citizenship, Engineering impact on society, Problem scoping, Empathy, Personal ethics,* and *Sustainability and Life-cycle analysis*. Students will develop proficiency in these areas under a system of micro-credentials, with incremental milestones leading up to graduate-level expertise.

Social Impact curriculum deep dive with industry

As a further input to the development of the Social Impact pillar, a dedicated workshop was held with industry representatives. The workshop involved participants discussing the meaning of social impact in engineering, and associated skills, knowledge, and attitudes. Participants also discussed the processes and issues involved in understanding the social impact of new designs and industry projects.

Some of the skills identified include emotional intelligence, self-awareness, and good questioning, which resonate with the key aspects of the Social Impact pillar: *empathy* and *communication*. Challenges identified with social impact include understanding the broader context of a project (e.g. social, political, historical, etc.), environmental impacts, financial concerns, and health and safety issues. Developing a curriculum and student experience to equip students with the skills to meet these challenges in the workplace is an ongoing focus in the continued development of the new degree program.

Conclusion

The new *Bachelor of Engineering Practice (Honours)* degree at Swinburne University of Technology is an exciting development in engineering education, doing away with outmoded traditional approaches to instruction, and in their place co-designing a new curriculum centred on work-oriented pedagogies and grounded in education research. Social Impact is one of four Pillars of project-based learning that will comprise a key aspect of the student learning experience.

In this paper, the ongoing process of integrating Social Impact into this curriculum has been described. An update of this process will be presented at the AAEE conference in December.

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Laboratory Learning: Hands-on versus Simulated Experiments

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Many universities and vocational training institutions conduct laboratories as simulated experiments. This is due to the costs and supervision needs to conduct hands-on labs safely. Numerous studies have presented mixed opinions on whether hands-on laboratory work is more conducive to learning than a simulated laboratory. Most of the studies put students from experimental and control groups in significantly different conditions. Therefore, it is hard to reach any definite conclusion regarding the influence of the learning mode onto the learning achievements.

PURPOSE This study compares learning outcomes of student laboratory work in an energy storages course conducted in two different modes: first as a practical hands-on exercise and second using computer-based simulations.

APPROACH In order to provide reliable insights, this study implements optimized research methodology to avoid any other effect (e.g. learning synchronicity/distance learning/instructions) on the learning outcome rather than the effect of the learning mode itself. The student laboratory experiments were created in a manner that they could be conducted in both modes in the same way and using a single set of instructions. To ensure a comparable group environment for the individual student, the students were arranged into two similar groups based on the student's practical experience. In this crossover study, the groups were taught the same topics by means of interchanging learning modes.

RESULTS To evaluate the influence of each mode on student learning, short written tests regarding the previous experiment were conducted at the beginning of the subsequent laboratory session. 102 students have taken part in the study in two years. Overall learning results of hands-on experiments were slightly better than those of simulated laboratories (Cohen's $d=0.25$), the difference in performance was statistically significant ($p<0.02$). Through solicited feedback on each laboratory session, in hands-on mode more students expressed they have acquired new insights/comprehensions (76% vs. 66%, Cohen's $d=0.23$, small effect, $p<0.07$).

CONCLUSIONS Following the strategy not to optimize the lessons individually to the learning mode, other influences on the learning outcome, which were usually mixed, were excluded. The students' subjective opinions show advantages of the hands-on mode. Based on the objective data, a weak, but significant outcome to better knowledge acquisition with hands-on laboratory experiments was achieved. This observation is against the trend of the literature in the last years towards better or equal learning with nontraditional labs. Some of the excluded factors might have a stronger influence on student learning than estimated previously. To get a clear view, the authors recommend isolated research.

KEYWORDS Hands-on vs. simulated experiment, battery experiment, learning-mode comparison

Introduction

Many universities and vocational training institutions conduct laboratories as simulated experiments instead of using the traditional hands-on way (Ma 2006, Brinson 2015, Heradio 2016). One reason is the cost of required lab equipment to conduct hands-on experiments. In case of potentially dangerous learning objects – like lithium-ion cells (Dahn 2011) – additional supervision is necessary to conduct traditional labs safely.

This study compares learning outcomes of student laboratory work conducted in two different modes: first as a practical hands-on exercise and second using computer-based simulations. Previous studies have presented conflicting outcomes (Ma 2006, Brinson 2015, Heradio 2016, e.g. Mathiowetz 2016, Sarabando 2016). After comparing the results of such research, Ma and Nickerson (2006) concluded that many studies did not allow to reach universally applicable conclusions.

Most of the studies put students from experimental and control groups in significantly different conditions. This is a result of separately developing and optimizing the teaching experiment in each mode, as the teachers/researchers do not see the modes as directly competing solutions for exactly the same objective, they prefer to accommodate different circumstances with both modes. For example, students conduct hands-on experiments in groups whilst on campus, but as off-shore students they are engaged in simulated exercises over the web and individually. Therefore, it is hard to reach a definite conclusion regarding the influence of the learning mode onto the learning achievements based on this kind of studies. As the change of modes is linked with other influences on the learning outcome (like changing learning objectives in the two modes, amount/type of supervision, cooperative learning effects, distance learning vs. learning in the university, and/or differing instructional papers) such studies always compare the combination of aspects. If these interfering aspects have stronger influences, the studies are unable to specifically identify the difference in learning effectiveness of one aspect (Lindsay 2005). This may explain the inconsistent outcome of present research (Ma 2006, Brinson 2015). Most of these other influences are difficult to describe clearly in written form, or just not mentioned in the publications. In order to provide more reliable insights, the present study follows an optimized research methodology to avoid many other influences on the learning outcome while comparing the modes. The student experiments were strictly developed in such a manner that the learning objectives and experimental procedure were matching in both modes.

Approach

In a crossover study, both groups were taught the same objectives, clustered into four content areas. All of the content areas were related to lithium-ion cells or battery systems. The first group learned the first and third area with traditional hands-on experiments while the second group was taught the same areas by computer-based simulations. The second and fourth areas were taught using the opposite learning mode in both groups.

In the beginning of the next laboratory session 10-minute long tests were conducted to evaluate the influence of the mode on student’s knowledge on the content areas of the previous experiment. To compare which mode has been more successful, the mean results for each group were evaluated. Moreover, the students were asked to reflect on their learning during each session in an online survey.

The experiment was conducted three times. Forty students of the study program "Electrical Engineering and Electric Mobility" at Technische Hochschule Ingolstadt (THI) were enrolled in the mandatory laboratory subject in summer-semester 2016. Thirty THI students were enrolled in summer-semester 2017. All students were asked to join the full anonymous study. Additionally an international summer school was included in the study to collect a broader database.

Learning objectives of the laboratory

It was decided to teach the most relevant transferable skills and knowledge that may be beneficial for the students' future careers. Thus, students should get familiar with the characteristic behavior and the most important parameters of battery cells. They should also gain knowledge on how to determine the parameters of battery cells self-sufficiently by means of appropriate experimental setups.

The recognized learning objectives where clustered into four main content areas: (A) contact and isolation resistance, (B) open-circuit voltage, (C) internal resistance and power, and (D) energy of cells. Grouped in these areas, seven laboratory experiments were conducted in both modes in the same manner:

- Low Resistance Measurements (A1): Students discover that a multimeter is an inaccurate tool for low ohmic measurements (milliohm range), and why such measurement is a misuse of this tool. They learn how to use alternative procedures for low ohmic measurements, including the four-wire measurement in AC and DC.
- Contact Resistance (A2): Students conduct experiments with a variety of typical electrical connections in battery systems to determine the contact resistance values.
- Isolation Resistance (A3): Students learn to estimate the influence of moisture on the isolation resistance.
- Voltage Curve (B): Students investigate the voltage of a cell depending on the state of charge. They use two different types of lithium-ion cells.
- Internal Resistance (C1): Students learn to use AC- and DC-methods to measure internal resistances, being aware of the temperature dependency of battery cells. Students learn to approximate temperature changes caused by power loss inside a cell.
- Power (C2): Students investigate the maximum discharge rate of battery cells. Students discover the dependency of maximum discharge power from state of charge, pulse duration, and temperature.
- Energy and Capacity (D): Students determine the capacity of a lithium-ion cell and learn about the factors influencing it. They learn to calculate the energy efficiency of charge and discharge cycles.

Each experiment was developed in parallel for both modes. Only a single set of instructions was created and then used in both laboratory modes, as instructions affect the learning outcome of an experiment, e.g. Chamberlain 2014 found, that the guidance level can influence student exploration.

Creating two comparable groups for the crossover study

In a crossover study, differences of the compared groups' average performances may be equalized by statistics. Nevertheless, with the goal of isolating the influence of the learning mode in the experiment, the authors had to consider the in-group interaction in laboratories. The same student may have different experiences in different groups, with consequent effects on his or her learning (van der Laan Smith 2007, Webb 1989). It was assumed that students with more practical experience might perform differently than their peers with a lesser practical background. Therefore the authors tried to create each of the two laboratory groups from students with a similar mix of practical skills. For the two study semesters of 2016 and 2017, an introductory questionnaire that asked students of their practical experience was developed. Its results were used for the group allocations. While completing the questionnaire, each student created a code-word that was used in the study to allocate the responses and test results to the appropriate individual, while keeping all participants anonymous. These code words were also used to assign students into laboratory groups. (Steger 2016)

Thirty-two students from the international summer school were allocated to groups to ensure similar distribution of the field of studies, number of study semester, and the nationality of the students in each group.

Conducting laboratories in content areas A to D

For each of the four main content areas a session with practical hands-on experiments and a session with computer-based simulations were established. Planned as a crossover study, each group followed the same sequence of contents, while alternating the learning mode between sessions. The first group handled the first content area with a computer-based simulation while the second group conducted it as a hands-on experiment. For the upcoming session both groups switched between learning modes. For the first content area, a specially created web tool was used for simulations. For the other areas a black box simulation of the battery cell and the hands-on equipment (Steger 2017a) was used. The battery simulation imitates all effects observed in the student experiments and was parameterized to match the battery cells which are used in the hands-on mode. To avoid any influence from user's interface, in both modes the simulation model was controlled by the same graphical user interface, a program to create the sequences for testing batteries. In both groups students selected companions to work in small teams of three to five students on the experiments. All groups and teams remained constant to avoid changing cooperative learning while the conduction of the semester lasting educational experiment. The laboratories were developed in a way to be conducted autonomously by the students in a supervised environment. All the learning targets were addressed through the experiment procedure/instructions, without essential explanations from the instructor. To pass the subject all learning teams had to prepare a written laboratory report for each content area.

During international summer school two trimmed content areas were taught on the same day; the same crossover principle was used as during ordinary semesters in 2016 and 2017.

Online survey after conducting the experiments

All student participants excluding that of the international summer school were asked to express opinions on their laboratory learning in a short online survey. It was conducted fully anonymously using the university's digital learning environment. Responses to the following survey questions were compared in order to evaluate the laboratory learning in both learning modes:

(a) "By conducting the experiment I gained new insights/comprehensions today." (German: "Ich habe heute durch den Versuch neue Erkenntnisse gewonnen.") This was a yes/no answer and coded 1 or 0.

(b) "At which point in the experiment did you have the biggest problem proceeding with the experiment?" (German: "An welcher Stelle im Versuch hatten Sie am meisten Probleme voranzukommen?") This was a free text question, which was not compulsory. For data evaluation, the information was coded to 1 if any problem was mentioned or to 0 if students wrote nothing or were expressing they had no problems.

(c) "The procedure of the experiment is quite difficult (1) / feasible (0.5) / easy (0)" (German: "Die Versuchsdurchführung ist recht schwer / machbar / leicht") The answers were coded in a three step Likert scale.

(d) "The content of the experiment is also relevant for me outside the university; I can imagine that it will be beneficial for my future professional life." (German: "Der Inhalt des Versuchs hat auch außerhalb der TH Relevanz für mich; ich kann mir vorstellen, im Berufsleben Gewinn aus dieser Versuchsdurchführung zu ziehen.") The answers were coded in a five step Likert scale: fully agree (1) / somewhat agree (0.75) / maybe (0.50) / somewhat disagree (0.25) / disagree (0)

Testing the learning outcome

Three written knowledge tests - each lasting 10 minutes - were used to determine the influence of the learning mode on student learning outcomes. Knowledge gained by students in a laboratory was tested just prior to the next laboratory session. A mix of descriptive and multiple-choice questions, free response, and drawings on the learning objectives of the previous experiment were used. The results were evaluated using a positive point system. The achievable number and the distribution of the points were set fixed beforehand.

As the tests were conducted anonymously, the students were distinguished by their self-created code words that were created by individual students during the Questionnaire on practical experience.

To exclude time influence on memorizing knowledge the authors aimed for equal time lapses between two sessions and thereby between experiments and its corresponding tests for both compared groups. Unfortunately this goal was not achieved regarding content area A in 2016 (Steger 2016). By conducting the sessions for both groups on the same day of the week it was easier to keep the time gap between the experiments and tests equal for both learning modes in 2017.

Independent of the learning mode, the same environment was established for both groups during tests. All students were able to sit at a desk in the same computer laboratory while working on the knowledge tests.

To find out which mode provides better learning outcome, average results for the test for each group were compared between hands-on and simulated modes.

Assessment of the influence of the study mode on learning outcomes of students that participated in the international summer school was similar to that of the students of peers that conducted laboratories during study semester. Due to logistical constrains, though, tests on the laboratory knowledge were administered to students as an examination one week after the experiments.

Results

Learning outcomes based on written tests

In year 2016 with 40 students for three content areas (A to C) a weak effect towards benefits of the hands-on mode was discovered. Hands-on laboratory sessions led to a better knowledge acquisition compared to simulated experiments. Content area D showed no difference between the modes. Overall learning results of hands-on experiments were slightly better than those of simulated laboratories (weak effect, Cohen's $d=0.22$), but the difference in performance was not statistically significant. (Steger 2016)

The second experimental run was conducted with 30 students in summer semester 2017. The range of individual scores was from 20% to 79% for hands-on, and from 15% to 77% for the simulated mode. For content areas A ($d=0.50$) and D ($d=0.80$, $p<0.02$) an effect towards benefits of the hands-on mode was measured. Content area C resulted in a weak effect ($d=0.14$) in the same direction, and content area B showed no difference between the modes. This run was demonstrating hands-on laboratory sessions led to a significant better knowledge acquisition compared to simulated experiments ($d=0.34$, $p<0.05$).

Additionally the learning outcome of 32 participants of the international summer school 2017 in Ingolstadt was evaluated. A short version of content areas B and C1 was taught. Independent samples T-test showed that content area B had no effect ($d=-0.09$), and content area C1 demonstrated a small to medium effect towards better learning in hands-on mode ($d=0.44$).

Overall learning results of hands-on experiments were slightly better than those of simulated laboratories (small effect, Cohen's $d=0.25$), the difference in performance was statistically significant (p<0.02). The correlation between an individual student's overall performance in the knowledge tests and learning better with simulations is very weak and insignificant (Pearson correlation 0.12, p=0.37, N=53).

Table 1: Learning Results Comparison

Research run	Number of Students	Std. Deviation of Percentage Points	Sample size N	Mean Value of Points	Sample size N	Mean Value of Points	effect size / Cohens d (pos = adv. of hands-on)	Student's t distribution / p-value one-tailed
		Both modes	Hands-on		Simulated			
THI 2016	40	17%	73	47%	75	44%	0.22	0.09
THI 2017	30	20%	58	56%	57	50%	0.34	0.03
THI SS 2017	32	24%	28	60%	28	56%	0.15	0.28
ALL	102	20%	159	53%	160	48%	0.25	0.014

In the 2017 research the pre-questionnaire was extended to ask for more detailed information. There was no correlation found between average mark in the study program and individual more effective learning mode (Spearman rho=0.03, N=24). Students who had not studied directly after school, but made a German VET (Vocational Education and Training, BMBF 2016), which is a dual (company & school) apprenticeship training and studied later (1st) have more hands-on experience (Pearson r=0.50, p=0.008, N=27) and (2nd) learn better with hands-on experiments compared to simulations (Pearson r=0.53, p=0.007, N=25) as they (3rd) have comparatively bad results with simulated experiments (Pearson r=0.47, p=0.017, N=25).

Online survey for student feedback

The student feedback results are based on all results of the first and second summer semester iteration. Student feedback was not collected during the summer school due to time constraints. Because fewer students responded to the questionnaire in 2016 (37%), an incentive was offered for completing the questionnaire in 2017 (Steger 2017b). The minimum passing score of 50% was reduced to 45% for participation in the online survey. As a result the return rate increased to 70% in 2017.

(a) In hands-on mode more students expressed they have acquired new insights/comprehensions (76% vs. 66%, Cohen's d=0.23, small effect, p<0.07).

(b) Slightly more students mentioned problems while conducting the hands-on equivalents (45% vs. 39%, Cohen's d=0.12, not significant, very weak effect).

(c) The engagement in the simulated experiments was stated to be a very small amount (5% of scale) more difficult. Cohen's d=-0.16 demonstrates a very weak effect, which was not significant.

(d) In the feedback form on the experiments, students who conducted the experiments in the hands-on mode rated the execution of the experiments a little more beneficial for their future professional life (58% hands-on vs. 54% simulation, Cohen's d = 0.20, small effect).

A significant correlation between (a) and (d) was found. It shows that students who claimed that they gained new insights also tend to believe that the execution of the experiment will help them in their future professional life (Pearson's r=0.36, p<0.001, Spearman's rho=0.35). Looking at both modes separately, this correlation in the simulation mode was little stronger (Pearson's r=0.39, p<0.001; Spearman's rho=0.40; N=86) compared to the hands-on mode (Pearson's r=0.30, p=0.115; Spearman's rho=0.27; N=92).

Interesting is a significant weak correlation that exists only in hands-on mode: Students who (c) stated a hands-on experiment difficult, tend to not (d) consider it beneficial for their future professional life (Pearson's r=-0.23, p=0.017; Spearman's rho=-0.22; N=86). Regarding simulated experiments Pearson's r and Spearman's rho is 0.04.

The actual methodology does not allow establishing correlations between individual learning outcome and student's feedback, as the standard online feedback form did not ask for the self-created code word that was used in the tests. The authors plan to request this missing information by updating a questionnaire and use the information for the next iteration.

Conclusions

Learning outcomes based on written tests

Following the strategy not to optimize the lessons individually to the learning mode, other influences on the learning outcome, which were usually mixed, were excluded. Based on the existing data, a weak, but significant outcome of better knowledge acquisition with hands-on laboratory experiments was achieved. This is against the trend of the recent literature that reported on better or equal learning with nontraditional (virtual/simulated) labs (Heradio 2016, Brinson 2015). Some of the excluded factors might have a stronger influence on student learning than estimated previously. To get a clear view, the authors recommend isolated research. The study on the mode will be continued through 2018 at THI and at more universities and training institutions with different types of students (e.g. international students, students enrolled in summer schools).

The average performance in the knowledge tests of a single student is independent from his better performing learning mode. It is important to note that this is the result of the created group environment, and may differ if one creates groups of high and low performers.

The difference between students that completed German Vocational Education and Training before studies and those who enrolled at university directly after school was interesting. Obviously, the VET-participants have more hands-on experience. This fact was confirmed by the study. The group creation questionnaire distributed the VET-participants equally to both groups based on the hands-on experience without using the VET-info. In 2017, 59% of the participating students in the study were VET-participants. Looking at the correlational data, this group learns better with hands-on experiments compared to simulations, as they have significant disadvantages while taught by simulations. Checking the 2017 results of the knowledge test separately, confirmed this point of view: VET-participants had a significant better learning outcome with hands-on experiments (Pearson r=0.56, p<0.015, N=60 tests), while non-VET-participants had no significant difference (N=37 tests).

Online survey for student feedback

The students' opinions show advantages of the hands-on mode. The effect between both modes in the student's subjective opinion about gained knowledge (a) is very similar to the objective results tests, even when student's expressions are less significant. Regarding mentioned problems (b) and stated difficulty (c) the experiments are considered equivalent. The slight, insignificant differences may be a result of statistical effects. To clarify this, more data collection is necessary. Asking the students to describe the laboratory difficulty in a free text answer may help to gain a deeper insight. Independent from the learning mode, more than forty percent of the students stated the opinion that they do not benefit in their future professional life from the experiments (d). There are slight advantages in the hands-on mode and it is planned to ask in future experiments for missing content students estimate as more important for their future profession.

The correlation between (a) and (d) suggests that students who believed that the execution of the experiment will help them in their future professional life also expressed that they gained new comprehension. The slightly stronger correlation between (a) and (d) in the simulations mode suggests that teachers should pay attention to explain the relevance of the experiment in simulated labs more carefully. Comparing the amount of positive answers in (a) and (d), one can conclude that the students do not consider all of the gained insights relevant for their profession. Identifying these insights may be beneficial for the improvement of the experiments. Future surveys will ask for the greater or lesser beneficial insights gained and whether these are considered useful outside the university.

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Fast-Cars in Schools: a CADET Outreach Initiative

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SESSION Educating the Edisons of the 21st Century

CONTEXT In order to provide for Australia's long-term needs for engineers, it has become apparent that the profession needs to promote itself to school-age children. This is so that the seeds of interest in engineering are planted early enough so that they can grow. Recent research indicates that this can be most effectively done in primary schools. Students tend to decide whether they have an interest in STEM fields before secondary school.

The Centre for Advanced Design and Engineering Training (CADET) was established as a facility for educating engineers, starting in primary school and providing facilities and expertise all the way to doctoral studies. One key component of CADET's mission is to provide outreach programs in engineering to students in both primary and secondary school.

PURPOSE A primary-school outreach program was developed to give students an authentic engineering experience in the context of developing a small racing car and working with an associated cross-disciplinary team. The program was designed to be completely immersed and integrated with the Victorian Curriculum at year six.

APPROACH The program was named "Fast Cars in Schools." Teams of students from a number of primary schools developed a complete racing package of a small car, team jerseys, logos, advertising posters, and even sponsorship. The teams then competed with each other to develop the best car and the best overall presentation. Members of the teams had specific roles on designing and building the car, designing and producing the jerseys, promotion, and reporting. In addition to tasks specific to the cars, participating students attended additional practical sessions on the physics and aerodynamics of racing cars, and how one's reaction times affect the outcome of a race. The program was fully integrated in the school curriculum over two terms. In developing a competitive racing car, the student teams were required to formulate their own questions of inquiry. Under the guidance of their teacher and assigned mentors, the teams also had to solve several basic engineering problems associated with producing a car that performs well in an actual race.

RESULTS The 2015 pilot program ran with a small number of schools in the Geelong region. In 2016, this was extended to 14 schools across Geelong and the Werribee region. In all, around 1000 students participated in the program. The final competition was held at the Deakin Waurn Ponds campus and was attended by 190 students. Feedback from teacher and students was overwhelmingly positive.

CONCLUSIONS The team successfully showed how the CADET centre is helpful to a school's curriculum needs and is not merely a destination for one-day excursions. By applying the educational concept of activity-based learning, the CADET team successfully integrated most aspects of the Victorian year-six curriculum into this program.

KEYWORDS Outreach; F1 in schools; primary school; Victorian curriculum.

Introduction

The shortage of engineers in Australia is well known, and does not appear to be going away anytime soon (Hoffman, 2017; Topsfield, 2006; Walton, 2012). A broader problem nationally is the inadequate number of school leavers and university graduates with training in the STEM fields, which includes engineering (Tytler, Osbourne *et al.*, 2008). This skills shortage may be traced to the lack of interest, or disengagement, of high-school students with STEM-related subjects. There is evidence that seeds of a high-school student's interest in STEM and the aspiration to pursue a career in STEM are sown in primary school (Archer, Osbourne *et al.*, 2013). Recent strategies for increasing STEM interest in high school include exposing and engaging students in primary schools to activities that promote STEM-related fields as exciting and attractive (Education Council, 2015). These activities include those related to engineering, such as design (Brophy, Klein *et al.*, 2008).

In 2015, Deakin University opened a new education centre called the Centre for Advanced Design and Engineering Training (CADET) (Loussikian, 2015). This centre provides engineering education opportunities from primary school right up to doctorates. The Centre rests on three foundations: university education in engineering, industry engagement, and school outreach. Indeed, one of CADET's main objectives is to "increase the awareness and attractiveness of engineering as an education and career option, particularly for women, in regional schools" (Littlefair & Stojcevski, 2012).

Numerous outreach activities exist with the goal of making STEM fields interesting to school students. Many are related to engineering. Since its opening, CADET has run numerous school outreach programmes aimed at students of all levels. The activities range from simple tours of the facility and labs, to short engineering-design projects, to preparing students for exams in years 11 and 12.

With this national goal in mind, CADET investigated and developed a primary-school outreach initiative that would engage students; and hopefully instil in them not only an interest in engineering, but an excitement for the field. Central to the activity are the practice of engineering design, and the need to engage all students, both those who are comfortable with maths and science and those who are not. Thus the problem considered here is whether an engineering outreach program can be developed that engages students in an immersive method of learning with a comprehensive approach to the process of engineering, and at the same time is fully integrated with the local school's curriculum.

Methodology of Fast Cars in Schools

The outreach programme described here is called "Fast Cars in Schools," a collaborative project between CADET, Catholic Education Melbourne, and a number of local primary schools. Fast Cars in Schools was designed to support year-5/6 teachers and students to engage in science, design and technology through the topic of 'Formula 1 Racing'.

A working party with representation from the schools established the curriculum goals and supported the design of assessment rubrics for the major areas of study, aiming for a deep-learning, inquiry-based experience for the students. Curriculum areas included activities for understanding science, mathematics, design, engineering and art, with options for considering humanities. Additionally the STEM skills and capabilities of ethical thinking, critical & creative thinking, and collaboration for learning, as well as the technologies for learning and literacy, social and emotional learning underpinned the inquiry. The education model behind everything was experienced-based learning (Andersen, Boud, & Cohen, 2000). Students were allowed to formulate their own inquiry questions and work out the answers themselves.

Fast Cars in Schools explicitly addressed several key learning areas found in the Victorian Curriculum: physical science, arts, media studies, mathematical data analysis, physical education, teamwork, leadership, and public speaking. At the same time, the programme allowed students to apply their learning in a practical, creative and exciting way. The programme was designed to run over two school terms, integrating all curriculum outcomes. It included a visit to CADET, a sports-performance workshop, trial racing days and a final race off day. The programme provided participating students with mentors from local secondary colleges, University students (including engineering students and pre-service teachers) to provide guidance to the teams through their investigations and decision making. It followed a team-based approach, and the tasks required from each team were more than design-and-build. The team was required to design a small racing car, find external sponsorship, design logos and a team T-shirt, produce a poster about their car, and give an oral presentation. This way, the team incorporated a range of skills from the students, not just those associated with designing and building the finished product.

The aims of Fast Cars in Schools were seven-fold:

1. For students to go through the process of designing, creating, testing, analysing, redesigning and retesting a car to race.
2. For students to participate a series of project based tasks linked to Formula 1 racing, the creation of the car and promotion to develop skills and knowledge in diverse areas linked to the curriculum.
3. To provide a platform for promoting group-based learning strategies.
4. To inspire young students to identify the value and application of STEM.
5. To support teachers in developing engaging STEM project based activities for students.
6. To support teachers in developing generic curriculum documents that may be used in any school linking required outcomes to aspects of the activities designed as part of the program.
7. To make connections between primary schools, secondary colleges, universities and industry.

Each team was made up of five students, and there were a number of specific assessed tasks:

- The team needed to design and create a car that would be raced on a 20-m track.
- The team created a poster that included the team's name, a logo, a photograph of the team and their car, a description of their approach to the problem of designing the car, and a description of the science behind their design that discussed technical aspects such as weight, friction, rolling, and aerodynamics.
- Each team was to give a five-minute oral presentation, which was assessed by a panel of judges.
- Each team designed and produced a team T-shirt.

The rules of the competition followed the template used by the international competition "F1 in Schools," junior-cadet class (Re-Engineering Australia Foundation, 2017). The centrepiece of the competition was a regulation cardstock racing car powered by a standard CO_2 soda canister. In Australia, F1 in Schools uses the cardstock racers mostly as a fund-raising tool, whereas the primary-school competition is run mainly in the United Kingdom. The teams raced their cars along a 20-m track, and the times for the trip were measured and recorded.

Originally the programme was aimed at schools within 25 km of CADET, but there were some participating schools up to 200 km away. The schools and their teams visited CADET twice each. In the first visit, the teams attended hour-long workshops on the physics of racing cars, basic aerodynamics, and reaction times, figures 1 and 2. (We note that written parental permission was granted to use and publish photographs of any of the participating children.) The workshops on reaction times were conducted by the Victorian BioScience Education Centre (BioLab, 2017).

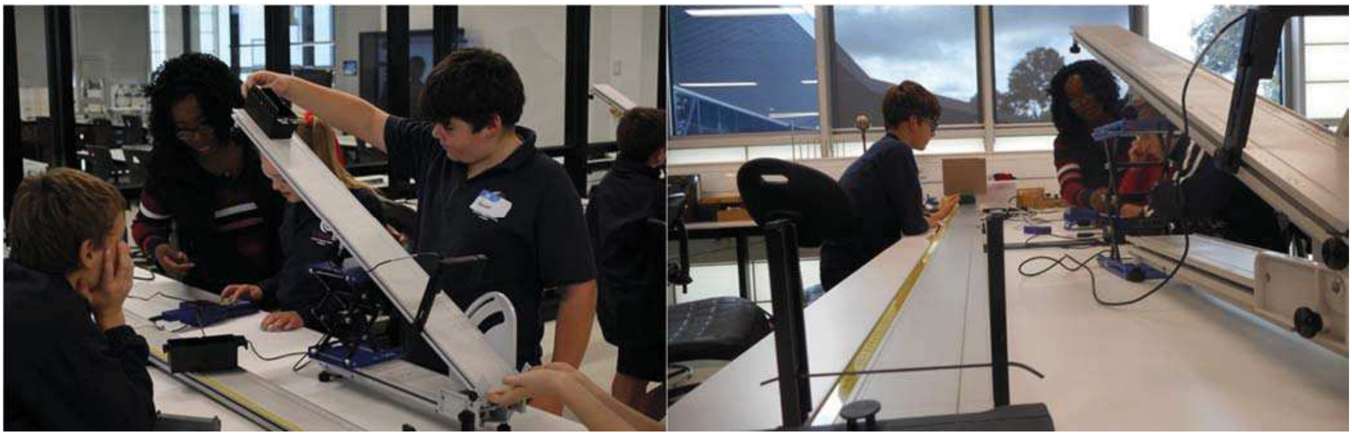

Figure 1: Students performing physics experiments on friction (left) and air resistance (right).

Figure 2: Students measuring reaction time.

After the first visit, the schools set time aside in their term schedules for the students to work on their designs, perform further physical experiments associated with the performance of their cars, and obtain lessons on the science and maths that lie behind the competition. For instance, one school had each team attend a double period (1.5 hours) once a fortnight to work on the project as part of its specialist curriculum. Class time was also spent reinforcing the lessons learned on physics and biomechanics that occurred during the earlier visit to CADET. Parental involvement was strongly encouraged and often obtained.

On the second visit, the teams competed with each other in the race, poster, and oral presentation. Each school ran qualifying heats and finals in school, then and sent their team with the fastest car for the finals, along with an additional wild card entry from each school. Additional curriculum-based projects were also assessed on the day and prizes and medals awarded in the major categories of team Logo/T-shirt design and A1 poster of the team's learning journey. Optional minor categories included visual design of the car and an oral presentation of the learning journey. These categories were judged according to scaled sets of judging criteria by an independent panel that included representatives of the University's School of Engineering.

For this study, we determined the success of the programme through anecdotal observations of the students competing in their races and making their presentations, and conversations with the teachers and school administrators.

Results and Discussion

After a small pilot in 2015, a larger programme was run in 2016. Most schools ran the programme in term 3. A few schools ran it in terms 2 and 3. All in all, 12 primary schools, 38 classes, and about 950 year 5 and 6 students completed the programme. Half of the students were boys and half were girls. The majority of participating teachers were women, the gender mix typically found in primary schools. Figure 3 shows some sample cars built by the students, and figure 4 shows one of the races.

Figure 3: Sample racing cars.

Figure 4: Students prepare to race their teams' cars.

From our observations, the response from both the students and their teachers was overwhelmingly positive. Students were clearly engaged throughout the activities. One teacher was impressed by the way his students were able to stay focussed on their tasks during the classroom sessions, even in a double period, and their ability to work out scientific processes that in a primary-school context are quite complicated. He also noted that in this programme, teachers learned new things as much as the students did. Some participating students, parents, and teachers were interviewed by one of the funding bodies and their thoughts published in two *YouTube* videos (Catholic Education Melbourne, 2016a, 2016b). The excitement of the students is clearly visible in these videos, as well as the satisfaction of the parents. The interviewed teachers stressed how the program successfully integrated many aspects of the state curriculum into the students' activities, while working in their teams towards an exciting goal. Table 1 shows some of the comments made by teachers on the day of the final race.

Table 1: Teacher comments at the conclusion of the final race.

Thanks again for such a fantastic day. The kids had the most wonderful time and learning experience.
A huge thank you for the F1 unit, the most successful unit I have had the opportunity to teach and hopefully it will be an option in the years to come!
Thanks for a wonderful day. The students were very happy to be a part of the experience.
Thanks for coordinating a fantastic opportunity for our students on Friday. They really enjoyed the friendly and approachable manner of the judges throughout the day.
Ashby kids learnt a lot and have had a fantastic journey.

The programme was vastly different from what a school usually does. Traditionally, educators tend to put learning into separate boxes (such as reading, maths, physics, design, technology, art). On the other hand, especially at the primary level, students take a cross-disciplinary approach to learning, which is clearly employed here. Thus this programme is well suited to how primary students actually think. It was quite a challenge designing this to fit the state curriculum.

Fast Cars in Schools integrated as much of the year-six Victorian curriculum as possible, and was assessed continuously as the students went through the programme. Each member of a team had a role, whether it be technical, artistic, or social. We must stress that this was neither a series of school excursions designed to market engineering courses, nor an extra-curricular activity, like the official F1-in-Schools. The students who participated were not taking an elective subject as there are no electives in primary school. It was not a pass-fail programme. It was a fully-integrated, whole-class learning endeavour, a far deeper learning experience than what one would obtain from a tour or a series of discrete learning activities.

We certainly intend to run this again in future years, subject of course to funding being available. We also intend to complete the education research by conducting interviews with the participating teachers (or better yet, the students) to see if there were any changes in their students' attitudes towards STEM in general and engineering in particular. It would also be interesting to track the students' selections of elective subjects as they progress through years 7-10.

Summary and Conclusions

An engineering-oriented educational outreach program for primary-school students was designed and trialled. The programme was designed to support the educational needs of the participating schools. The team engaged primary schools into understanding how the CADET facility might be useful for their curriculum delivery. We successfully integrated the Victorian year-six curriculum into the programme through the practice of experiential-based learning. The feedback that was received by participating students, parents, and teachers was exceedingly positive. To finish this research, we intend to interview the teachers involved to see whether they notice any longer-term interest in science and engineering in their students as a result of this experience.

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Generating an architectural brief for a twenty-first-century engineering education working and learning environment.

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SESSION C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments.

CONTEXT This paper reports on the process undertaken by the Engineering Practice Academy at Swinburne University of Technology to broker and construct an architectural brief for a working and learning environment for a new engineering course. An architectural brief is a document that specifies the requirements and frames a project in regard to the project values, visions, and objectives. The construction of an architectural brief that is responsive to a specified espoused culture, values and objectives requires shared appreciation and meaning between the project stakeholders and decision-makers; this can be a complicated process as it entails the brokering of perspectives. In this case, representatives of the Engineering Practice Academy (Academy) who participated in the generation of the architectural brief were conduits of their own and collective desire for how engineering education and learning environments can be and should be delivered now and into the future.

PURPOSE To generate the conceptual content for an architectural brief that is viewed as a socio-spatial artifact.

APPROACH Stakeholders of the Academy participated in two participatory design workshops that addressed the built environment of the Academy as a signifier of an espoused culture. The workshops were organised around Schein's (2010) structural model of organizational culture and a reflection-in-action process was used to structure the workshop activities.

RESULTS The workshops became a catalyst for the generation of the textual content for the architectural brief that was co-owned by the project stakeholders of the Academy who are advocates of the future environment and the emerging culture of the Academy.

CONCLUSION Brokering of shared meaning and practices is paramount to ensure that cohesive understanding of practices, identities and positions amongst project-stakeholders are negotiated, and ownership of a project and the eventual built environment are formed. The case presented in this paper is an example of one process for generating shared meaning and delivering an architectural brief viewed as a socio-spatial artifact for an engineering working and learning environment.

KEYWORDS Engineering working and learning environment, brokering, shared meaning

Introduction

This paper reports on the process applied by the Engineering Practice Academy at Swinburne University of Technology to broker and construct an architectural brief for a working and learning environment for a new engineering course. This paper details the initial phase of a longitudinal study that is investigating being-and-becoming a twenty-first-century engineer and the ontological conditions that enable such a process within a university. Being-and-becoming is influenced by authentic learning through and about practice, engagement with others and, the artifacts that produce the material world (Dall'Alba, 2009a, 2009b; Dall'Alba & Sandberg, 2010, 2014; Heidegger, 2011; Sandberg & Dall'Alba, 2009). This paper applies the understanding that the artifacts that create the material world in which education and knowledge are delivered can afford meaning and the construction of engineering practice knowledge.

When completed, the Engineering Practice Academy (Academy) environment will be a purpose-designed space for educating future engineers and preparing them for twenty-first-century engineering practice. The new Bachelor of Engineering Practice (Honours) degree at Swinburne University of Technology is a new approach to engineering education, where students will join and work within a functioning engineering practice set up on campus for their four years of study. They will work on industry projects, community-based projects and other activities as if they were in practice from their first day. Students will be mentored by academic and industry mentors, and graduate work ready. The built environment in which the Academy will be situated is being purposely designed to enable the culture and activities of the Academy. The process to design the built environment is a shared responsibility between Academy stakeholders, university decision-makers and the employed architect.

Project stakeholders (university decision-makers and facility managers) engaged with university planning and construction, are conduits of the values and vision of a university. The built environment of a "university can invite or reject dwelling through its built-in vision and enterprise, emerging from the values, views and virtues of those who envisioned it" (Nørgård & Bengtsen, 2016, p. 8). Meaning, the built environment of a university is a signifier of the values and vision of the university and thus, "supports and promotes particular being and becomings in education while stifling and preventing others" (Nørgård & Bengtsen, 2016, p. 8). This paper delivers an account on the process undertaken by the stakeholders of the Academy who included university decision-makers, Academy employees and, engineering educators to construct and articulate the espoused culture, values and objectives of the Academy. The outcome of this process was the generation of the conceptual content for the architectural brief of the Academy's desired built environment.

The production of an environment that is responsive to a specified espoused culture, values and objectives require shared understanding between project stakeholders in regard to what the espoused culture, values, and objectives will be. The creation of mutual understanding is complex and requires stakeholders to broker their perspectives and positions on the given project. Shared understanding requires the relational understanding of the individual and the collective with respect to who will be using the environment and the value of the environment to those users. An understanding of the individual is important because it asks that stakeholders interrogate their assumptions and to acknowledge the assumptions of others. An architectural brief is part of the initial stages of the conception of a built environment, and it is a "decisive interactive element" (Ryd, 2004, p. 248) that is a product of the social structures of the stakeholders who constructed it.

An architectural brief is a socio-spatial artifact created by societal assumptions in regard to the occupation and usage of an environment. An architectural brief "rather than prescribing the end solution" (Haug, 2015, p. 50) documents requirements and frames the project with respect to project values, visions and objectives. Stakeholders who construct an architectural brief are therefore projecting their visions of occupation. In the case of this project, stakeholders who participated in the generation of the architectural brief were conduits of their own and a collective desire for how engineering education can be and should be delivered now and into the future.

A values-lead environment articulated through a participatory design approach

A built environment is "coded with signifiers of value and power" (Charteris, Gannon, Mayes, Nye, & Stephenson, 2015, p. 41) that can be welcoming towards some individuals and "unwelcoming towards others" (Nørgård & Bengtsen, 2016, p. 8). Stakeholders of the Academy participated in two participatory design workshops that addressed the built environment of the Academy as a signifier of an espoused culture. Participants accepted the perception that universities, and the fact that the Academy, being situated within a university had an opportunity to address systemic issues in engineering education and had an obligation to advance personal, academic and societal value of engineering education. The built environment that will house the Academy is just one of the strategic signifiers and manifestations addressing the ontological conditions of being-and-becoming a twenty-first-century engineer. The outcome of the participatory design workshops was a co-constructed architectural brief. The participatory design workshops were structured around Schein's (2010) structural model of organizational culture whereby, culture is a product of individual and collective assumptions, espoused values and, artifacts.

Participatory design is "about negotiating values" (Iversen, Halskov, & Leong, 2012, p. 88), the values of prospective end users, project champions and project stakeholders. A participatory design process can be considered a values-led approach that facilitates and generates through designed activities a consensus of shared values and shared meaning for a project. A participatory design approach is, therefore, a "mutual learning process and a co-construction of problem and solution" (Bredies, Chow, & Joost, 2010, p. 167) between participants and the design facilitators, who are considered co-designers of the solution. A designer, regarded as a maker of things and "sometimes he makes the final product; more often, he makes a representation - a plan, program, or image - of an artifact, to be constructed by others" (Schön, 1995, p.78). The stakeholders of the Academy who contributed to the participatory design workshops were considered designers of the espoused culture of the Academy. The participants were conduits of the articulation of an authentic engineering practice, where there will be relationships between university and society that "are in and for each other" (Nørgård & Bengtsen, 2016, p. 14) in the support of being-and-becoming a twenty-first century engineer.

This paper focuses on the first phase of articulating the built environment as an artifact of the espoused culture of the Academy. Within the context of Schein's (2010) work, artifacts are a visual and verbal signifier that afford meaning and provide material context to a situation. Applying Schein's structural model of organizational culture presented a theoretical framework in which to deliver workshop activities and also undertake a reflection-in-action process whereby, the insights from workshop one was communicated and enacted upon before and within the succeeding workshop. Reflection-in-action provides a frame to acknowledge that culture is emergent and it is through the cycle of implementation and reflection that informed development occurs, leading to a desired co-constructed outcome.

Research method: Participatory design workshops

Participatory design workshops are designed to challenge participants assumptions regarding the given system, service or product in question. Furthermore, participatory design as a method presents the belief that:

> *all people have something to offer to the design process and that they can be both articulate and creative when given appropriate tools with which to express themselves (Sanders, 2002, p.1).*

Participants who engaged in the Academy workshops involvement and exposure to the Academy varied from being a founding member of the Academy to being newly appointed employee within the Academy. In total, there were eight participants with seven participants in workshop one, six participants in workshop two and five participants in attendance at both workshops. The workshops were designed and facilitated by two design researchers who were at the time external to the academic staff of the Academy. The facilitators were presented with the single constraint being, that the outcome of the workshops needed to be an architectural brief that communicated the requirements of a working and learning environment for engineers that were grounded by values.

The two workshops were structured to implement a reflection-in-action process meaning that the workshops were designed to facilitate a process of individual work and reflection followed by sharing and collective participation. Structuring the workshops in such a way provides the opportunity for individual voices to be heard and understood before a collective voice is created. The workshop facilitators compiled the visual and textual data produced during the workshops, synthesized it and returned an insights report to the participants before the succeeding workshop.

Workshop one focused on generating shared-meaning through the articulation of individual and collective current and future assumptions of the Academy. Activities included:

- Generation of a visual language: participants were presented with an assortment of images and instructed to select five images that represented their vision for the academy. Participants were further told to document through text, specifically words that depicted activities and behaviour, why they had selected the images. Participants shared the outcome of the task and the language formed became the foundational descriptors for the built environment within the architectural brief.
- Generation of a statement of intent: participants were instructed to write down a single point-of-view statement for the Academy using the words generated in the previous task. Participants collectively evaluated the generated point-of-view statements looking for similarities, differences and eventuating in a single shared statement of intent.
- Create a vision for a desired future state: Participants were then separated into two teams of four and instructed to produce a utopian vision story of the Academy, a story from the perspective of a student and the point of view of an industry partner. The participants were instructed to answer four questions that addressed (1) desired activities undertaken in the Academy, (2) a reaction or quote about a future users' initial encounter with the Academy, (3) a response or quote that expressed a future user sustained experience with the Academy and, (4) an urban legend about the Academy. Participants imagination and assumptions controlled the accounts of the multiple prospects of the Academy. The stories became a conversation piece for what the social and material environment of the Academy could and should be if the various utopian stories were to happen.
- Statement of intent reflection: Participants were instructed to reflect on the previously generated statement of intent. Participants collectively produced the statement of intent: *A collaborative community and dynamic practice engaging and empowering engineers by disrupting convention to improve the world.*

Workshop two built upon the outcomes of the activities conducted in workshop one. Workshop two was focused on the generation of espoused values and unpacking the desired culture of the Academy. Activities included:

- Addressing Schein's approach to organisational culture: Participants were instructed to brainstorm their assumptions and exposed values for the Academy individually. Participants were then instructed to communicate and describe the artifact and symbols which presented relevance to the assumptions and values because assumptions, exposed values, artifacts, and symbols do not exist in isolation and thus each level of culture needs to be identified and addressed. Participants then individually reflected and provided feedback on their peer's work using an I like / I would like to know more activity;

framing feedback as a positive keeps communication channels open. Following individual reflection, participants were instructed to have an open discussion focusing on the statements identified as being *I would like to know more*.

- Concentrating on artifacts: Participants were directed to use the lexicon generated in workshop one in conjunction with the outcomes from the previous task to brainstorm an ideal built environment of the Academy. Participants were guided to select a value of the Academy and address perceived challenges or barriers that impedes this value. Participants were then instructed to generate a spatial consideration concept that would overcome this perceived challenge or barrier. Participants completed the task individually than shared back to the group.

Results: Brokering shared understanding

Including individual and co-constructed content within the architectural brief transforms a document from being an individual constructed artifact to being a socio-spatial artifact that is co-owned by project stakeholders. The two workshops became a catalyst for project stakeholders to communicate and co-construct the values and cultural framework to inform the working and learning environment for being-and-becoming a twenty-first-century engineer. The resultant outcome from the workshops was a considered architectural brief that presented dimensions of delivering twenty-first-century engineering practices. The architectural brief provided information on:

- The context of the project that included the property details and background on the Academy.
- The Academy's espoused values.
- The project objectives that communicated the Academy being an activity-based working and learning environment for staff, researchers, students, and industry.
- A section titled, *this is not*, that outlined what the Academy wished to avoid in regards to both cultural and environmental structures.
- Project considerations that outlined how the Academy environment needs to engage with the social fabric of Swinburne University and the wider community.
- Components of the built environment that would facilitate a flexible, and transparent working and learning environment.

Workshop participants generated the textual content for the architectural brief. The textual content was produced during the *visual language* activity and provided the lexicon for the architectural brief (refer to figure 1). The *visual language* activity highlighted that why participants are attracted to an image varies and the language used to describe the activities and behaviours an image depicts to them differs. No participant who selected the same image used the same descriptive words to explain why they had made the selection. The outcome of *visual language* activity underlined that the lexicon used to describe environments relies on a number of similar words however, there is disparity in the understanding of what these words mean and represent. Words such as; open, private, multi-layered, inspirational, engaging and, professional to name but a few are words that produce ambiguity when commonly used as descriptors by both those who create particular environments and those who occupy them. The *visual language* activity brokered not only the individual's desires for the Academy built environment but also mitigated understanding of. For example. what a collaborative environment represents both physically and metaphysically and what a collaborative environment would symbolise within the context of the Academy.

Human aspects I **Mastery** I Futuristic I **Inspirational** I Playful I Open I **Industrial** I Interaction I Professional I **Collaboration** I Multi-layered I Creative I Colour I Experiment I Transparent I Next Generation I Reflective I **Engaging** I Friendly I Desirable I Present I Open + Private I Inspired by nature I Informal I Making stuff I **Community** I **Connected** - staff + students I Joyful I Sound - silence, buzz, white noise I Formal I Outside I Different Space I Evidence I Raw - Unfinished I Connected to outside I **Educating the whole person** I Virtual / Physical - seamless I Zones I **Empowering** I Flexible I **Personal - sense of home - sense of place - sense of belonging** I Distinctive I Serving a purpose I Has a hum

Figure 1: Co-constructed lexicon that informed the textual content of the architectural brief. Words that multiple participants used were presented in bold.

Through a reflection-in-action participatory design workshop process, participants engaged in a cycle of individual work and reflection followed by sharing and collective participation and participants identified five working espoused values for the Academy. The workshop process confirmed that the sooner a consensus of shared meaning of stakeholders is brokered, the more the architectural brief will reflect the expressed requirements of the espoused values. The five working espoused values being:

- equity and diversity,
- respect,
- working and learning are social,
- collaboration and,
- openness.

The five values were considered working espoused values because through an iterative process of reflection and implementation the values will be tested and refined as the Academy develops and expands. The working espoused values, as shown in figure 2, continued to evolve since the completion of workshop two and was taken into a further two workshops that were designed to specifically address the generation of the espoused values for the Academy.

Creating shared meaning before an architect is contracted provides the foundation to consider and question the spatial consideration of the future built environment concerning whether the proposed outcomes will support or hinder the application of the espoused values. Academy stakeholders, expanded on the meaning of each value and how the built environment could be viewed as a manifestation of that value. For example, the recognition that working and learning are socially transpired in the architectural brief as:

> *The environment will encourage and facilitate the curation, sharing, iteration and documentation of both individual and collective working, learning and knowledge generation. The environment needs to facilitate: team-working and individual working modes for all occupants (staff, students and industry). The division between shared and owned and individual and collective environments is important. The inclusion of an open kitchenette / cafe space with a large communal kitchen table: traverses socializing and working.*

The value of openness and specifically the sub-definition of *we cannot prescribe or predetermine what will be experienced* was characterised within the architectural brief as:

> *The creation of an emergent environment that is scalable and malleable. The environment needs to adapt over time and be responsive to new practices that materialize in response to changing activities, projects and occupants. The environments need to be designed in such a way that they can be adapted depending on the requirements of the occupants and the projects. The environment needs to be scalable in as much that if the current proposed rooms*

do not provide adequate space for the activities, projects and occupants of the Engineering Practice Academy modifications and/or additional rooms can be incorporated at a later stage.

Articulation of a practices purpose within an architectural brief is crucial because a brief is the "communication of instructions about intention and objectives" (Ryd, 2004, p. 231) and if the project stakeholders who are representatives of the university are not on shared ground, clear communication is potentially jeopardised.

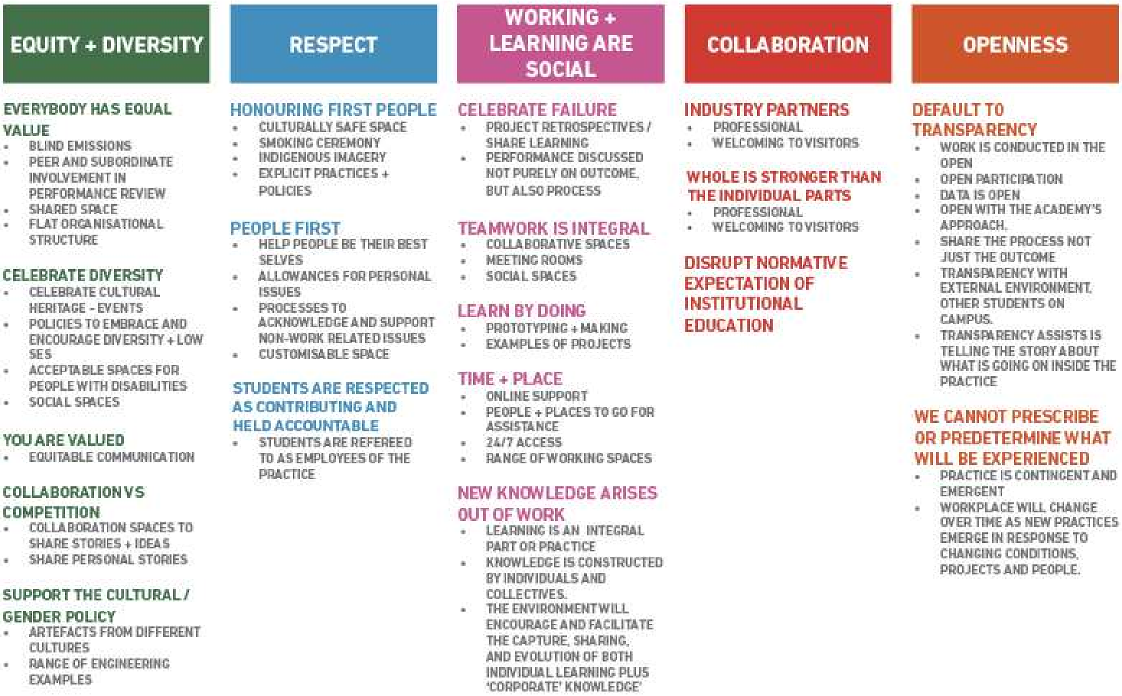

Figure 2: The working espoused values of the Academy that informed the content of the architectural brief.

Conclusion

The construction of a twenty-first-century working and learning environment for engineers is complex because it brokers the boundaries and positions of humans who are directly and indirectly involved in the project. Brokering a consensus of shared meaning and practices is paramount to ensure that negotiation of understanding, practices, identities, and positions amongst stakeholders is formed, and ownership of the project generated. The case presented in this paper is an example of one process for producing a consensus of shared meaning and an architectural brief viewed as a socio-spatial artifact.

This interpretive study proposed that the key challenge inherent in the generation of shared knowledge is brokering individual positions and perspectives. Brokering involved negotiating shared meaning through facilitated participatory design workshops. The workshops were structured to promote both personal and collective working and reflection time allowing for individual voices to be understood before a collective, harmonious, voice is constructed. The workshops produced an environmental lexicon for the architectural brief, a shared consensus of the mission statement, cultural meaning, values and outcomes to inform the architectural brief.

Culture and environments are intertwined and political because of project stakeholder's perceptions and individual perspective that typically extend the parameters of the project. An individual's perspective is influenced by historical, cultural and material factors that extend the boundaries of the project. However, without understanding the espoused culture and activities of an environment, it is difficult to communicate to an architect the intention for such an environment.

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Implementation of Project-Oriented Design-Based Learning in a Second-Year Mechanical/Mechatronics Subject

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SESSION Integration of theory and practice in the learning and teaching process.

CONTEXT The School of Engineering at Deakin University has undergone a significant transition towards making design and projects the basis for the undergraduate curriculum rather than the more traditional approach based on lectures, texts, and examinations. A new curriculum, called Project-Oriented Design-Based Learning (PODBL), is now in its second year of implementation. The curriculum allows for approximately one half of the total content in the course to be based on design projects.

PURPOSE This study seeks to study and evaluate the effectiveness of a second-year mechanical unit in the new PODBL curriculum.

APPROACH SEM200, Machine Design, was developed as a new two-credit-point unit in the Bachelor of Engineering, mechanical and mechatronics streams. It runs in the first semester of the second year, and is takes up one half of the total content in the semester (two credit points). The remaining half of semester is shared between a unit on engineering mathematics and another on fluid mechanics (one credit point each). The main project for this unit is centred on the design of a mechanical-based machine that must perform a defined set of tasks with a defined set of criteria. The project aims to reflect a real-world engineering project environment. Students work in teams. The assessment consists of a team project plan, a team presentation of the final product, an interim report, and a final portfolio. The unit is offered both to on-campus students at Geelong and online.

RESULTS The unit been offered twice – in 2016 and again in 2017. The project for both years was to build a robot following the rules and specifications of the Engineers-Australia Warman Design-and-Build Competition. Forty-eight students completed the unit in 2016, and 100 students completed the unit in 2017. The average mark for 2016 was 66/100, and for 2017, the average mark was 67/100. Student reviews of the unit were mostly positive and the teaching team have learned a number of important lessons that will influence further offerings of this and other PODBL units.

CONCLUSIONS SEM200 is the third two-credit-point project-design unit in which mechanical and mechatronics students enrol. The academic performance of the students indicates that the content and assessment is appropriate for second-year students. The student feedback suggests that although the unit involves a great deal of work, students enjoyed both the challenge posed by the unit and the satisfaction of completing a complicated design project in the space of a single semester.

KEYWORDS Project-oriented design-based learning; PODBL; projects; design.

Introduction

A recent trend in engineering education in the past 15 years or so is the shift from an emphasis on the science of engineering to an emphasis on problem solving, projects, and design. This is one of the five major shifts in engineering education recently identified by Jeff Froyd of the IEEE (Froyd, Wankat, & Smith, 2012). Design is now commonly seen in engineering education as a very important component and that which distinguishes engineering from other fields such as applied physics.

The School of Engineering at Deakin University has very recently redesigned its Bachelor of Engineering courses to make design projects a major component of the curriculum. Deakin offers undergraduate courses in civil, electrical/electronics, mechatronics, and mechanical engineering. About 30% of the School's undergraduate students attends the University almost wholly online (Long, Joordens, & Littlefair, 2014). The revised courses use design projects as the focal points of learning. The new curriculum is called Project-Oriented Design-Based Learning, or PODBL (Chandrasekaran, 2013a; Chandrasekaran, 2013b). It developed from significant research into aspects of project-based learning, problem-based learning (Chandrasekaran, 2014; Chandrasekaran, Stojcevski *et al.*, 2012), and the School's long experience in teaching design projects (Chandrasekaran, Long, & Joordens, 2015; Joordens & Jones, 1998).

The PODBL model is a learning and teaching approach that is based on engineering design activities while driven by a project. It has been proposed to use PODBL in Deakin Engineering to encourage independent learning and a deeper approach to learning. It is also an approach that supports the development of information literacy and design thinking in the field of tertiary education - two of the key learning outcomes in engineering these days. There are many versions of project based learning as well as design based learning. Deakin's engineering approach is a unique combination of the two (Joordens, Chandrasekaran *et al.*, 2012). PODBL indicates that students learn through real engineering design activities while driven by a project that has a defined deliverable, and is presented to the students with an industry partner or an academic staff.

The new PODBL curriculum was designed to cater for online students (Maung-Than-Oo, Chandran, & Stojcevski 2014) as well as the more traditional on-campus students (Chandran, Chandrasekaran, & Stojcevski, 2013; Chandrasekaran, Littlefair *et al.*, 2014). Early trials of the PODBL approach in an electrical-engineering unit have been presented elsewhere (Chandran, Chandrasekaran, & Stojcevski, 2014, 2015). The new, full PODBL curriculum was first offered in 2016, and is currently rolled out to the first, second, and third years of the course. Fourth year will be offered from 2018.

The PODBL curriculum specifies that one half of a student's studies will be in the context of a design project. In the previous curriculum, each semester comprised four units of study, or eight each year, for a total of 32 units. Each unit was one credit point (cp), 0.125 EFTSL, apart from the final-year capstone project units, which were two cp each (0.25 EFTSL). In the PODBL curriculum, each semester has one two-credit-point design/project unit, and two one-credit-point support units covering core engineering concepts. For example, table 1 shows the course structure for the Bachelor of Mechanical Engineering. In a typical two-cp PODBL unit, the unit content is emphasised in the first half of the 11-week semester, and most of the lecture material is delivered then. In the second half of semester, the class-time shifts towards design-studio and project work. Students are normally put into teams. Most units follow the University's Cloud-Learning model (see for example, Long, 2015), where most lecture material is delivered by means of videos posted to the unit website, and class time is focussed on studios, seminars, and active learning.

Our previous AAEE presentation described the development of the first-year unit Engineering Fundamentals, one of the one-credit-point support units (J. M. Long, Chandrasekaran, & Orwa, 2016). In this paper, we present the first results from a fully-integrated, two-cp PODBL design unit: SEM200, Machine Design. We report on the design and delivery of this unit to mechanical and mechatronics students in 2016 and 2017, both on-campus and online. We present the unit's intended learning outcomes, the structure and delivery of the unit, the students' academic performance, their satisfaction with the unit, and the lessons we learned in this exercise.

Table 1: PODBL Course structure for BE Mechanical.

First year			
Sem-1	SEJ101 Design Fundamentals (2 cp PODBL)	SEB101 Engineering Fundamentals	SIT199 Applied Algebra and Statistics
Sem-2	SEJ103 Materials Engineering Project (2 cp PODBL)	SIT194 Introduction to Mathematical Modelling	SIT172 Programming for Engineers
Second year			
Sem-1	SEM200 Machine Design (2 cp PODBL)	SEP291 Engineering Modelling	SEM218 Fluid Mechanics
Sem-2	SEM201 Structural Design (2 cp PODBL)	SEM216 Stress and Failure Analysis	SEM202 Thermodynamics
Third year			
Sem-1	SEM300 Thermo-Fluid System Design (2 cp PODBL)	SED304 Product Development	SEM313 Manufacturing
Sem-2	SEM301 Industrial Control (2 cp PODBL)	SEM302 Advanced Stress Analysis	SEM327 Dynamics of Machines
Fourth year			
Sem-1	SEJ441 Capstone Project 1 (2 cp)	SEM400 Computational Fluid Dynamics	Engineering elective
Sem-2	SEJ446 Capstone Project (2 cp)	SEM406 Advanced Modelling and Simulation	Engineering elective

SEM200 Machine Design

SEM200 is a project-and-design-based unit that allows students to develop technical and professional practice skills relevant to machine design. The unit runs in the first semester of the students' second year. Students build on fundamental knowledge previously acquired in engineering design, engineering fundamentals, project management and professional communication. The main project for this unit is centred on the design of a mechanical-based machine that performs a defined set of tasks with a defined set of criteria/rules. SEM200 has six learning outcomes. Students who complete and pass the unit can:

1. Develop, implement and complete a project management strategy in a project team for the design and build of a machine to specific requirements.
2. Recall discipline specific knowledge relating to mechanical and mechatronic machines and machine elements.
3. Apply discipline specific knowledge relating to the design of machines in order to develop innovative engineering solutions.

4. Identify and communicate occupational health-and-safety (OHS) considerations of stakeholders and professional engineers.
5. Communicate effectively and in a professional manner to convey both technical and non-technical content.
6. Communicate design process, mechanical and mechatronic concepts, and evaluation of product, professional ethical considerations, and reflection of project team performance through a professional portfolio.

The student assessment is a mix of individual and team items:

- Team project plan 10%,
- Individual online tests (2 x 5% each) 10%,
- Team project gateway presentation 10%,
- Individual project gateway report 15%,
- Team product demonstration/showcase 20%,
- Individual final project portfolio 35%.

The unit's project centres on a modified version of the Warman Student Design-and Build-Competition that is run annually by Engineers Australia (Churches & Smith, 2016). In 2016, the competition required students to build a machine that would deliver a payload after crossing a gap between two table-tops along an upward-sloping pole. The machine had to find the pole, attach itself and traverse the pole, drop off the pole and drive to a destination. In 2017, the competition requires students to design and build a robot that collects golf balls, squash balls, and racquetball balls, separates the golf balls from the others, and places the golf balls into one container and the remaining balls into another container (Engineers Australia, 2017). The students were divided up into teams of six students each. Each team worked on its robot, completing it in time for a unit competition in the final week of semester. Figure 1 shows examples of the projects built by the students in the two years the unit has been offered.

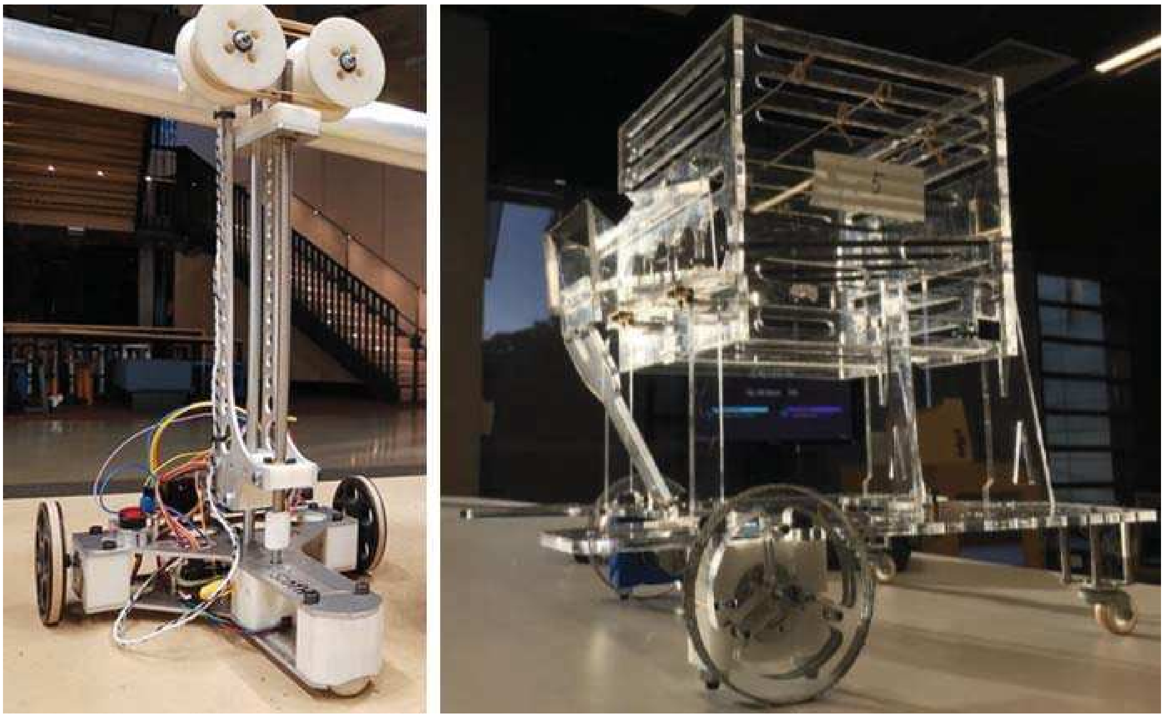

Figure 1: Examples of student-built machines for the SEM200 projects for 2016 (left) and 2017 (right).

During the 11-week semester, weekly on-campus class time is divided up into two lecture classes (one hour each), seminar/tutorials (two hours each), and practical studios (two hours each). Each student attends both lectures, one seminar, and two studios each week. Lectures and tutorials were used to convey the primary unit content to the students. They used the studios to work on the project in their teams. In addition, the studios allowed the teaching team to scaffold the learning towards the requirements and deliverables for the project. Engineering topics covered in the unit include computer-aided design (CAD), Arduino programming, project management, safety, mechanical and mechatronic components, and ethics (table 2). Lectures, seminars, and many studios were video-recorded and posted to the unit website for the benefit of all students, on-campus and online. Weekly online seminars and two-hour studios were held by means of the *BlackBoard Collaborate* web-conferencing software (Long, Cavenett, Gordon, & Joordens, 2014). On-campus and online students were brought together in week 7 as part of the School's residential week for all students.

Table 2: Weekly class topics and activities.

Week	Lecture topics	Seminar topics	Studio topics
1	Introduction; Project and team management	Review of CAD basics	Introduction to Warman Competition and benchmarking; teamwork
2	Product development (PD) process overview; PD Problem formulation	Part and assembly modelling	Team and project management; Prototyping
3	Design for safety; PD concept development;	Advanced assemblies	Safety by Design; PD problem formulation, concept development, concept screening
4	Intro to machine elements: gears, cams, bearings, links, pulleys	Detailed design in CAD	Detailed design considerations 1; Team check-up and assignment work
5	Intro to mechatronics: transducers, actuators, sensors, basic control	Intro to Arduino, basic control systems, programming	Detailed design considerations 2; Intro to basic mechatronic components
6	Machine elements calculations 1	CAD communication and project work	Mechatronics practical activities
7	Scheduled classes, studios and seminars replaced by two full days for Intensive Week for both Campus and Cloud students	Intensive Week focuses on activities related to Project Gateway tasks	Intensive Week will also focus on professional practice activities (OHS, WSA, ethics in engineering design)
8	Machine elements calculations 2; Mechanical design and safety factors	Machine elements - CAD and hand calculations	Ethics in engineering design; Discussion and feedback from Intensive Week and Project Gateway tasks;
9	Drawings, dimensioning, tolerancing	Arduino programming review and	Finalise design and/or work on manufacturing prototype
10	Tolerancing; Mechanical failure	Part drawings	Finalise prototype build
11	Tolerances 2; SEM200 review/summary	Assembly drawings	Finalise prototype build; Campus competition - practice and final

Methodology

For this study, enrolment numbers, student final marks and attrition were examined for 2015 and 2016, for both on-campus and online students. Student satisfaction was also examined by means of the University-wide standard survey of completing students. In the student-satisfaction survey, 12 questions are posed to the students and the students indicate their agreement on a Likert scale (table 3). Students are also invited to make written comments on aspects of the unit with which they are happy and aspects most need of improvement.

Table 3: Survey questions on student satisfaction.

No.	Statement
1	The learning outcomes in this unit are clearly identified.
2	The learning experiences in this unit help me to achieve the learning outcomes.
3	The learning resources in this unit help me to achieve the learning outcomes.
4	The assessment tasks in this unit evaluate my achievement of the learning outcomes.
5	Feedback on my work in this unit helps me to achieve the learning outcomes.
6	The workload in this unit is appropriate to the achievement of the learning outcomes.
7	The quality of teaching in this unit helps me to achieve the learning outcomes.
8	I am motivated to achieve the learning outcomes in this unit.
9	I make best use of the learning experiences in this unit.
10	I think about how I can learn more effectively in this unit.
11	Overall, I am satisfied with this unit.

The survey is anonymous and the data collected is used for research purpose without any identification linked to it. The research study survey was approved and acquired a ethics clearance from the Human Ethics Research Committee at Deakin. The students are not compelled by any teaching academics to participate in this survey. It is not compulsory and it will not affect their marks or curriculum participation in anyways. The survey was given by a third person who is not part of the teaching team. The cohort of students are aware of participation based on their own consent.

Results

Table 4 shows the academic results for this unit. On average, on-campus students performed at a Credit level, whereas online students performed a bit better, a low Distinction. There were few differences in academic performance from 2016 to 2017. Student satisfaction results are given in figure 2. In 2016, from 17 answered surveys (on-campus only), and in 2017, from 24 answered on-campus surveys and 11 from online students, the results indicate that students were very satisfied with most aspects of the unit. The lowest scoring area was in relation to feedback on student submissions (statement No. 5). It can be noted that on-campus satisfaction on this statement increased significantly from 2016 to 2017. Most students were satisfied with the delivery of the unit.

It is evident that in 2017, the student satisfaction results were above the School average on most questions. When both on-campus and online student satisfaction scores are combined, the 2017 survey shows results that are above the School average in all but one area (feedback). Averaging all responses for all questions in 2017, the survey results show that the percentage agreement for SEM200 was four percentage points above the School average.

The survey also provides the student the opportunity to provide written comments on what aspects of the unit they found helpful and what areas need improvement. Due to space limitations, the full detail of these comments cannot be included in this paper. However, the authors have attempted to summarise the main results of these here. Regarding the helpful aspects of the unit, the most number of written comments were relating to the project itself, its hands-on and practical nature, the fact that it was a “real” problem that was being solved and the fact that the project allowed the students to complete a full design cycle from concept development, to detailed design, to building and testing. Qualitatively, the areas where the student comments noted needed most improvement were relating to: the timeliness and amount of feedback; the high workload associated with this unit (although it is a two cp unit); the requirement to sort through and digest a large amount of information and content; and the need to focus more on project management techniques.

Table 4: Summary of academic marks 2016-2017.

Cohort	No. students competed	No. students withdrawn	AVG final mark (%)	Standard deviation	Median final mark
2016 on campus	44	4	65	13	64
2016 online	4	3	71	6.8	72
2017 on campus	72	5	65	11	65
2017 online	28	4	72	11	72

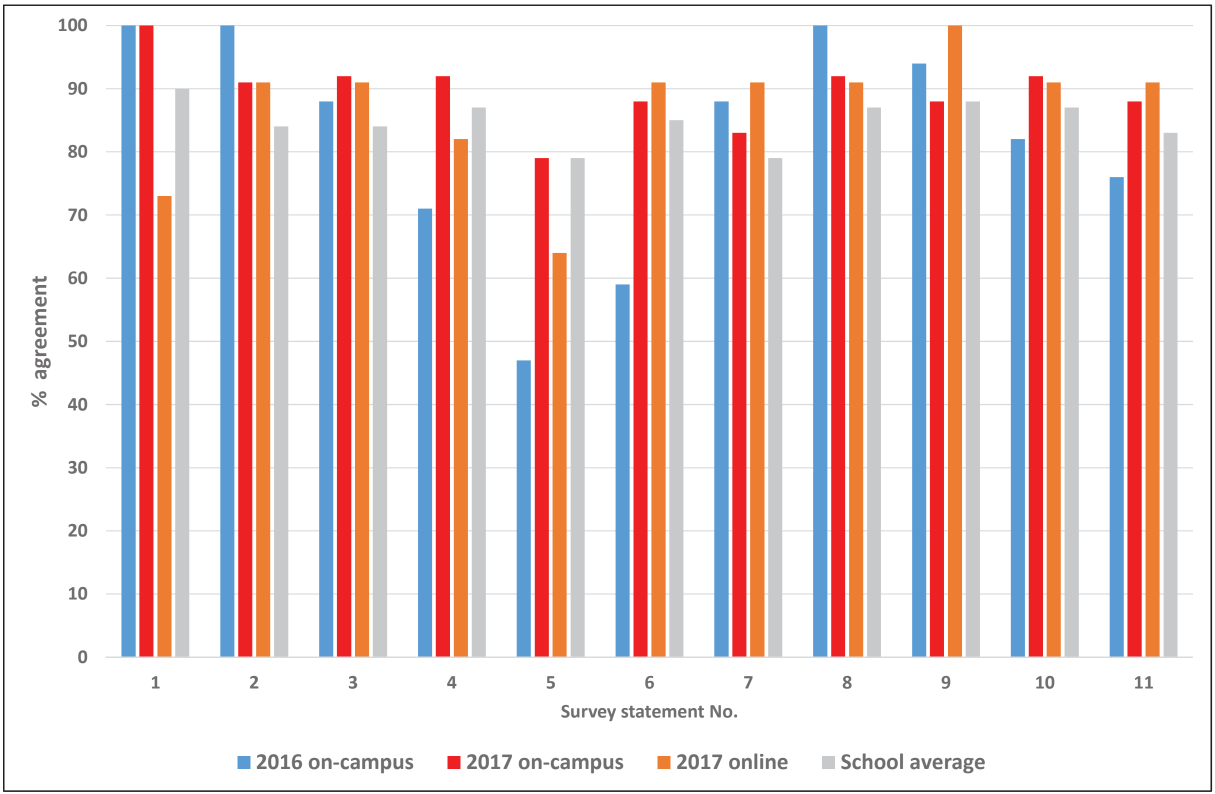

Figure 2: Results of the student-satisfaction survey.

Discussion

This is the first time Deakin has developed an engineering unit based on the Warman competition. There are only a few universities in Australia with engineering courses that use Warman as the basis of an engineering-project unit, such as ADFA (UNSW Canberra), Monash University, University of Newcastle, and RMIT. Apart from RMIT, these engineering units are Deakin's equivalent of one credit point. Like RMIT's MIET2420, Mechanical Design 1, SEM200 is two credit points.

In his study, Felder identifies 'Engineering Design' as a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints (Felder & Silverman, 1988). Design problems are classified as open-ended problems that generally have multiple solutions. A formal systematic problem-solving methodology is useful for these types of problems. Design is a continuous process of problem solving that many involve multiple iterations. The design process starts by identifying the problem. This allows students to search for possible opportunities to assist them in understanding the problem and therefore develop a design brief. Through research, students can then gather information on different methods, approaches and ideas to allow them to seek new solutions (Atman, Adams *et al.*, 2007; Bailey & Szabo, 2007). When a new solution is implemented, a model or prototype is developed. The prototype is then tested and evaluated against the specifications developed in the design brief for functionality.

In a PODBL environment, participants work in teams of four to six members with a facilitator. The same group meets regularly throughout the trimester to work on a series of design activities. The learning and teaching delivery is a combination of cloud and located learning activities. Cloud learning enables students to evidence their achievement. Units contain integrated short, accessible, highly visual, media-rich, interactive learning experiences rebuilt for the mobile screen, and integrating learning resources created by Deakin and other worldly universities and premium providers. Cloud learning require students to be generators of content, collaborators in solving real world problems, and evidence their achievements in professional and personal digital portfolios. With located learning experiences in place, students who come to campus will have the opportunity to engage with teaching staff and peers in opportunities for rich interpersonal interaction through large and small team activities.

As mentioned previously, the area which scored the lowest with respect to the student-satisfaction surveys was with regards to student feedback. However, this was also one of the areas of largest improvement from 2016 to 2017 – i.e. an increase of over 21% when considering both the online and on-campus students. The improved results in this area can be attributed to: (i) improved rubrics and assessment criteria for assessment tasks, which also aided in (ii) improved timeliness of feedback, and (iii) increased informal discussions between teaching staff and teams during studio activities on progress towards project.

Additionally, the area of largest improvement in the student survey results from 2016 to 2017 was relating to statement No. 6 – *The workload in this unit is appropriate to the achievement of the learning outcomes*. This was particularly interesting considering that the student workload was not reduced from 2016 to 2017. (In fact, it may have increased slightly with some small modifications to the assessment tasks.) However, more attention was given by the teaching team to ensure that the teaching and learning activities (including the course material, seminars, studios and assessment tasks) were explained with respect to how they aligned with the learning outcomes of the unit. It also worth noting that the academic marks between 2016 and 2017 do not show any notable differences (Table 4).

Finally, the survey results show some small differences between the on-campus and online students. However, considering the average of the percentage agreement for all statements in the survey in 2017, it is evident that the online students resulted in a small 1.8 percentage points less agreement compared to on-campus students. The largest differences were relating to statements No. 1 and No. 5. The academic results showed that the online students performed better than the on-campus students. This aligns well with the experience of academic staff at Deakin University, where the demographic of the online students are skewed towards mature-aged students with trade or similar qualifications and so tend to perform better with more applied/practical units.

In 2017 the third year of the PODBL curriculum is being offered for the first time. In addition to refining this unit for 2018 and beyond, we intend to consult the lecturers of the third-year PODBL units to gain further insight into the students' conceptual development, and to ensure that in terms of the conceptual knowledge required of graduate engineers, nothing is left out.

Summary and Conclusions

The implementation of Project Oriented Design Based Learning was successfully in the second-year unit of the undergraduate mechanical engineering and mechatronics degrees. Over 140 on-campus and off-campus students have completed the unit over 2016-2017 with student satisfaction that was in general above the school average. Feedback from students will be used to improve the delivery of the unit in future years.

Project Oriented Design Based Learning is generally regarded as a creative and innovative method for engineering education. When compared to traditional lecture-based or teacher-centered engineering curriculum, the PODBL model appears to inspire an enhanced learning environment for students. The conversion and implementation of this particular unit from the Mechanical Engineering program to PODBL is a gateway to enhance the relationship between the program and current University practices in the future.

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The Immersive Learning Laboratory: employing virtual reality technology in teaching

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SELECT SESSION

C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

CONTEXT

Virtual reality (VR) technology has revolutionized educational opportunities by allowing people to experience and interact with diverse environments. Many environments in which professional engineers and scientists work are restricted from students due to safety and logistical constraints. Moreover, immersive technology can complement textbook based learning with visualization and immersion as an engaging medium. To transform the learning experience at The University of Sydney an innovative Immersive Learning Laboratory (ImmLL) was established under this project. The laboratory will enable academics to teach using immersive content based on interactive 360° videos of real environments or constructed virtual realities.

PURPOSE

The ImmLL is a new learning environment which pilots innovative teaching methods using VR to optimise the student learning experience and educational outcomes.

APPROACH

The project was split into four stages. In stage I, several of the current VR platforms were evaluated and tested in order to select the most suitable for teaching purposes. The laboratory space was also designed to maximize the learning and teaching experience. In stage II, a series of workshops were conducted to assist in training academics to develop their own learning material to use in the space. Stage III and IV are currently running with teaching sessions and an evaluation of learning experiences at the laboratory as of Semester 2 2017.

RESULTS

Technology testing was conducted with the two main brands of VR equipment; HTC Vive and Oculus Rift. Based on several criteria including user experience, quantity of content and the preference for seated experience, the Oculus Rift was selected as the preferred VR headset. The laboratory was fitted out for 26 Oculus Rift and high-performance computer units. Twenty academics from four different faculties were given training on the technology and content creation for 360° videos and virtual reality teaching. During Semester 2, the teaching and learning experiences will be evaluated. It is expected that positive and engaging learning outcomes will be found with some minor challenges around employing the new technology and user experience (motion sickness).

CONCLUSIONS

To our knowledge the ImmLL is the first laboratory of this scale for VR teaching in Australia. It is breaking new ground with an emerging technology and initial findings show promise in its ability to provide the highly engaging and motivating learning environment of the future.

Introduction

Virtual environments in 3D and simulations have been widely used in training and education to deliver abstract concepts and encourage active learning. Immersive VR enables students to visualize, experience and interact with diverse environments otherwise not accessible due to safety and logistical reasons. VR technology assists in bringing real-life working environments to classrooms, to transform the learning experiences of the future engineer and scientific workforce. Freina and Ott (2015) listed immersion, interaction and user involvement of VR technology as the three principal characteristics that have high potential to engage and motivate students. Dede (2009) also outline the potential of VR to motivate and engage students through situated learning, multiple perspectives and transfer to real-world settings.

VR technology can primarily be categorized as non-immersive and immersive. While non-immersive VR provides a virtual environment by projection on a screen or a desktop, immersive VR typically utilizes a head mounted display (HMD) and emphasizes presence – the perception of “being there” (Soukup, 2000). The use of immersive VR has been limited due to the associated high cost of hardware and technical and usability issues (Freina & Ott, 2015). However, the latest advances in immersive VR technology has made it more affordable, opening new opportunities in both research and education.

Non-immersive VR was the first step in virtual technology education and it was demonstrated to be an effective teaching method (Warburton, 2009), with the ability to improve learning outcomes (Ijaz, Bogdanovych, & Trescak, 2016). Recently, affordable VR setups such as the Oculus Rift (Oculus VR, 2017b) and HTC Vive (HTC, 2017) have overcome the challenges faced by earlier systems. There has been a noticeable growth in educational applications exploring VR, augmented reality (AR) and mixed reality systems. For example, an immersive 360-degree video for surgical education was recorded from a camera mounted on a helmet (Ros, Trives, & Lonjon, 2017). This immersive experience has allowed medical trainees to experience first-hand operating room procedure through the eyes of the lead surgeon and it was assessed as a valuable pedagogical exercise. Izard et al. (2017) demonstrated another application teaching anatomy using interactive internal virtual body exploration. The discipline of science has lead the exploration in VR teaching and engineering is starting to make advances in this space.

Construction safety education is an important part of the civil engineering curriculum. Peña and Ragan (2017) point to a lack of methods to effectively contextualize safety information in an engaging way. These authors developed an interactive VR system using real incident reports to teach construction safety. Preliminarily results suggest better student engagement with the learning environment. Immersive technologies such as AR and VR are effective tools to develop 3D visualization experiences to facilitate multidisciplinary design education (Camba, Soler, & Contero, 2017).

VR environments, 360-degree videos and AR have the potential to assist educators to teach using innovative teaching methods (Astbury, 2016). In addition, the author accentuated the vital need to train educators who can further provide immersive educational experiences and in order to successfully integrate this technology as a standard medium. Immersive technologies can not only engage regular classroom students but also has the potential for distance learning (Potkonjak et al., 2016) and are inclusive learning environments for differently abled students (Pavlik, 2017).

Purpose

The purpose of this work is to report on a pilot initiative taken by the University of Sydney to employ immersive VR technology in undergraduate and postgraduate learning. This paper discusses the approach followed to introduce immersive VR for learning, the various stages of planning and the deployment of innovative technology, the training of academics and teaching cases currently taught in the laboratory.

Approach

The pilot project was divided into four stages based on the proposed objectives and the requirement of a 12 month project timeline.

Stage I: Initial setup

In stage I, extensive testing of VR technology was performed to decide on the technology best suited for teaching and configuration of a teaching space. The aim was to select technologies that supported a range of VR experiences including 360-degree videos and constructed virtual reality environments. Based on this initial technology decision, we further evaluated both HMDs for several aspects including cost, procurement logistics, scale in terms of deployable units, technical complexity, space requirements, content availability, future VR development as well as after sales support. To support content creation, 360 cameras, including drone mountings, were also investigated.

Stage II: Training Academics and Tutors

The aim of stage II was to empower academics to develop and/or select their own educational VR content in the form of immersive 360 videos or virtual environments. Through introductory workshops, academics and tutors were given an orientation of ImmLL. The lesson plan for the sessions included training to use the VR hardware, basic configuration settings and an overview of available VR content. After experiencing both 360-degree videos and VR applications an engineering teaching case was discussed.

Developing 360 Videos

In a second workshop, the aim was to train academics in the overall workflow from recording to playing 360-degree videos. Detailed guidelines were prepared with step by step instructions on how to record, edit and play 360-degree videos using Adobe Premiere or as an independent application using the game development software Unity.

Constructed Virtual Reality Environments

The third workshop was to assist those academics who wished to build custom VR environments. This workshop focused on software tools, platforms and workflows to develop VR environments. A guideline was prepared to demonstrate how to visualize 3D models and data. Additionally, instructions were given about how to use existing VR applications to produce educational content following a simple workflow.

Stages III and IV: Teaching and Evaluation

Stage III of the project was the delivery of teaching commencing in August, 2017 (semester 2). An online booking system was created to facilitate the scheduling of tutorials from units of study where the academic had completed the workshop training. Student numbers and experiences were recorded during the semester.

Evaluation is the final stage of the project and consists of a voluntary online survey for student participants and academic teaching staff. Ethical clearance was sort through University Human Ethics Committee. This evaluation is set to be complete by the end of semester 2.

RESULTS

Stage I: Initial set-up

Two available HMDs that fitted the primary criteria were Oculus Rift with its touch controllers and HTC Vive. In stage I, Oculus Rift with touch controllers was selected after a detailed VR testing to choose the best hardware to support the learning. We found that there was a variety of content available for both platforms and both could support diverse immersive content. During testing of both technology setups, the Oculus Rift had fewer tracking issues and had a relatively lower risk of trip hazards for multiple users in a confined space. The Oculus Rift also provides a better seated experience and needs less seated space per user (approximately 1 m^2). Considering that we intended to design a space for tutorial sessions (max 20 - 24 students), the Oculus Rift was found to be the most suitable technology. This technology evaluation lead to the purchase of 26 sets of Oculus Rift HMDs, touch controllers and high-end VR PCs (Intel i7, Asus Z270 motherboard, 16 GB of RAM, 500 GB M.2 NVMe SSD, Nvidia GTX 1080 graphic card). Moreover, two 360-fly 4K cameras (360 Fly, 2017) and a 3DR drone with Kodak PIXPRO SP 360 cameras (Kodak, 2017) were purchased to produce 360-degree videos. Table 1 lists the pros and cons of the respective VR setups for use in an educational space.

Table 1: Technology selection by criteria (pro '+' con '-')

Criteria	Oculus Rift	HTC VIVE
Cost	+ AUD $900	- AUD $1400
Procurement	- Ships from USA	+ Local purchase
Number of units	+ Individual trackers mean better scalability	- Multiple units compatible with one sensor set - Sensor screening and interference
Technical set-up	+ Less cables - Tracking issues - Sitting experience	+ Tracking accuracy - Cables as a trip hazard - Standing experience
Space	< 3 m^2 (sitting ~1 m^2)	~ 4 m^2
Content platforms	+ Oculus Rift store apps + 360 videos free	+ Apps and content available + More interactive content
Future Proofing	+ A tech start-up, now Facebook owned	+ Backed by HTC
Support	- Limited	+ Support via regional offices

Immersive Learning Laboratory Space

The decision to adopt the Oculus Rift guided the design of the laboratory's physical space to support the target tutorial size for learning sessions. To facilitate both immersive teaching and content development the lab space was divided into two work zones. Two VR desks at the front were allocated for content development to enable content creation activities in parallel to teaching sessions scheduled in the lab, as depicted in Figure 1. Three height adjustable desks in the first bay were also installed for disability access.

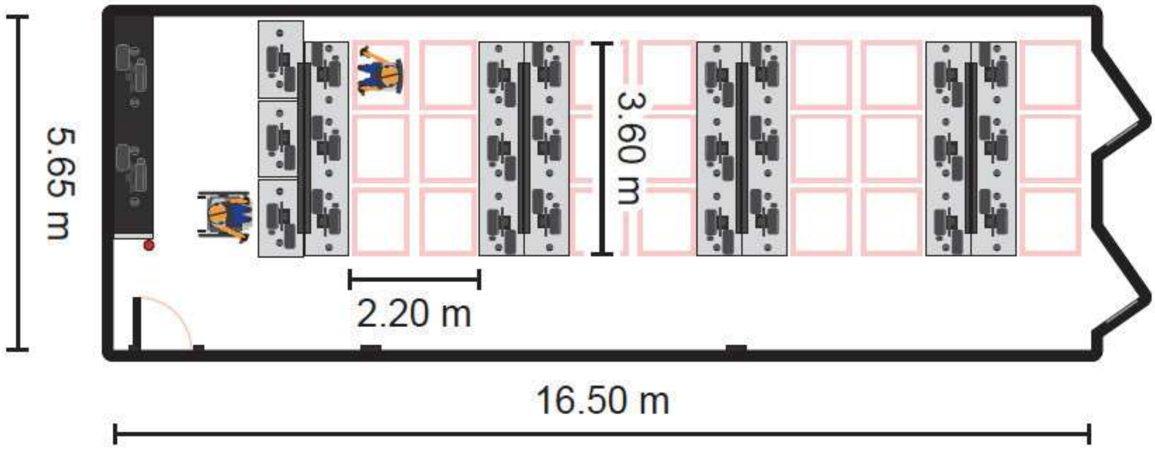

Figure 1: Floor Plan – development and teaching space. Top view with pink boxes indicating the sensor area for each computer.

Stage II: Training Academics and Tutors

In total 20 academics and 19 tutors from four faculties were trained to conduct teaching in the introductory workshops. Academics used the Oculus First Contact tutorial (Oculus VR, 2017a), Google Tilt Brush (Google, 2017b) and Google EarthVR (Google, 2017a) to familiarise themselves with the technology and its capability. Common problems experienced with academic attendance at the training was their limited time to participate in the workshops. During the workshops three out of 20 academics reported motion sickness and two out of 20 reported that the HMD was uncomfortable while wearing glasses. These reports will be compared to those reported during student use in Stage III. Academics indicated concern about the time required to produce content from design to teaching execution and the resources required. In the initial workshop, some academics showed interest to bring immersive field trips to their classes. This was one way to give experiences of real-life situations of work sites or places not easily accessible to students.

360 and virtual reality content creation workshops

Only seven academics attended the content creation workshops. This was a clear indicator of the concern of academics over the amount of resources required for content creation. It was not aimed for academics with these diverse backgrounds to develop unit specific material within the workshop, but rather the academics were guided to understand the amount of effort and cost involved to develop custom environments. We discussed the possibility of using existing VR educational applications and provided technical contacts to prepare their immersive teaching material.

The development support provided by this workshop was instrumental in reducing the time and cost of producing the quality immersive content. Academics were also given a hands-on experience with using 360-fly 4K (360 Fly, 2017) and a 3DR SOLO drone with Kodak PIXPRO SP 360 (Kodak, 2017) cameras. Also, attendees learnt to edit and publish a sample video for use in VR. The ImmLL technical team offered support to academics for development where requested to execute timely teaching sessions.

Stage III and IV: Teaching and Evaluation

Stage III has commenced with teaching sessions being held in the ImmLL. In semester two 2017, 11 academics from four faculties (engineering, science, architecture and arts) and six schools booked teaching sessions, as shown in Table 2. There were 19 trained tutors who assisted academics during these sessions. In total, nearly 600 students enrolled in seven subjects are expected to learn course specific tasks using the lab in 2017. A running teaching session is depicted in Figure 2.

Figure 2: A teaching session in the laboratory

Based on the experiences with academic workshops, minor motion sickness and problems with the wearing of glasses were anticipated. However, with two thirds of the teaching complete only one student reported feeling uncomfortable with a fear of heights. To date there have been no students reporting motion sickness, which is likely due to a younger generation having more experience with this type of technology. To improve the user experiences, we ensured that an ImmLL team member was available to support the first session for each subject.

During teaching, it was observed that the sensor area (marked by the pink box in figure 2), spontaneously reset. This caused the user to view content from an awkward angle, sometimes rotated 180 degrees. The exact technical cause of these spontaneous sensor area resets is not known. The solution for a teaching environment was to move the student to another unit and reset the computer, with subsequent recalibration of the sensor areas.

Table 2: Current teaching in the laboratory (not including final year thesis)

Discipline	Subjects	Students(N)	Content
Engineering & IT	CIVL2010 Environmental Engineering	240	360 videos and 3D models
	CIVL3310 Humanitarian Engineering	35	
	ENGG5103 Safety Systems and Risk	50	
	CIVL3206 Steel Structures	50	
Science	BIOL1997 From Molecules to Ecosystems	35	360 videos, 3D models and 3D VR applications
	PHSI3911 Physiology	18	
Art and Social Sciences	ARIN6904 Mobile Media and Games	180	VR/AR applications
Total	7	608	

Teaching Case I: Humanitarian Engineering

Humanitarian Engineering is offered as a third-year elective which introduces the role of engineers in development, disaster relief, remote communities as well as global sustainability. Students frequently did not have any experience firsthand of development or disaster contexts and it was a challenge to reach the desired learning outcomes through lecturers and reading material alone. Tutorials in the ImmLL were designed to increase students understanding through 360-degree videos of urban informal settlements and rural villages. JAUNT VR (Jaunt, 2017) is one application that has a wide selection of 360 degree videos, an example of which is 'Women on the move' based in Niger, West Africa. The students viewed the content and were then allocated a frame (time point) in the video to make detailed observations around a particular engineering focus (water, energy, transport or building construction) and report back to the class. Student informal feedback was that they felt that they are actually present in the 360 video and it really opened their eyes to how things really were. Engagement in class was high and students were excited to be using the new technology.

Teaching Case II: From Molecules to Ecosystems

This unit examines the function of biological organisms and their interactions with local ecosystems down to the molecular level. First year science students delve into the microscopic universe of beyond cells, to the structure and function of various biomolecules including DNA and proteins at the atomic level and gain understanding of how their interactions are crucial for homeostasis. Structural modelling of these molecules was particularly important not only in gaining an appreciation for how intermolecular forces are at play in the folding of proteins, but also to recognise key motifs in protein structures and how these contribute to the reactivity and function of protein enzymes. To improve student understanding of protein function by structural modelling of proteins using Blender and interacting with these structures in 3D space using Unity3D in the ImmLL. These tutorials additionally introduced the students to the need for digital literacy in the field of biology in the 21st century through basic exposure to 3D modelling software and game development principles. This exercise aimed not only to facilitate the retention of theoretical knowledge delivered during lectures but also to expose students to 3D modelling, game development and basic scripting.

Teaching Case III: Steel Structures

Third year undergraduate students enrolled in steel structures (civil engineering) course used immersive VR environment to investigate portal frame structure. The aim was to allow students to understand well the sense of scale by navigating around the structure as they can in person. This was more realistic experience than simply looking at the structure on a 2D screen. This sense of scale includes a realistic span to height ratio of the structure, bay spacing, section depths of all the main frame members, including beams, columns, and cross-bracing, etc., and relative sizes of all the members (relative to each other). Another main goal was to have students better understand connection design. They could see how physically the connections are formed and how everything fits together, and in a realistic scale, and again sizes relative to each other (bolts and stiffeners to main frame members). Virtual environment was built in Unity using Sketchup models where students could navigate and observe various details of the frame structure.

Conclusion

ImmLL has proved to be a successful pilot project for The University of Sydney. Academic and student verbal feedback received has clearly demonstrated that immersive VR education is perceived as an engaging teaching tool across multiple disciplines in a higher educational environment. Initial reports are positive from the 11 academics conducting teaching sessions in ImmLL who have delivered immersive learning experiences approximately 600 students enrolled in seven subjects across three different faculties, however the detailed evaluation in stage IV will give more insight. Future plans for ImmLL are to continue in its current configuration for 2018 with additional academics teaching with the technology. The University of Sydney already has plans to include VR technology in new purpose-built facilities at a larger scale.

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Towards the development and delivery of sustainable assessment in foundation engineering studies

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C3: Integration of teaching and research in the engineering training process

CONTEXT Boud (2000) has argued that higher education assessment must be sustainable so it “meets the needs of the present and prepares students to meet their future learning needs”. Within engineering education, sustainability means tasks should have real-world currency and encourage lifelong learning and self-regulatory competence. Portfolios are a widely adopted assessment practice in engineering which aligns well with understandings of sustainable assessment; however, many students have not experienced this assessment before entering higher education. Mismanaging the implementation of these assessments at critical times such as first encounters can often result in student bewilderment and frustration, potentially leading to increased attrition.

PURPOSE The study aimed to develop effective scaffolding and supports for introducing portfolio assessment to first-year engineering students in response to student voice data.

APPROACH An action research approach was adopted to examine the implementation of portfolio assessment with a cohort of Engineering students from diverse backgrounds. Students’ experiences of this portfolio assessment were gathered via surveys where they were asked to rate assessments on the ‘value’ of their learning, how much ‘effort’ was required to complete them and how ‘difficult’ they were to complete. These investigations, along with student satisfaction and results, informed significant revisions to the assessment structure of the unit in 2016 and further refinements in 2017; while the largely cross-sectional design means that such data cannot establish that one approach was more effective, they can provide some anecdotal evidence of improvements in the student experience.

RESULTS Data indicated that unit revisions might have improved both students’ experiences and their academic achievement. For example, Absent Fail grades fell in 2017 to only seven down from 17 in 2015. Also, the 2017 cohort achieved an increase in grade point average of 4.91 up from 4.27 in 2015. Improvements in student satisfaction in areas of assessment tasks, learning resources and Moodle navigation were also noted.

CONCLUSIONS These data suggest that not only could students see the benefit of portfolio assessment, but that introducing it in a structured and scaffolded way potentially improves the student experience and also their academic results.

KEYWORDS Portfolio assessment; Student success; Foundation studies

Introduction

Boud (2000) has argued that higher education assessment must be sustainable so it “meets the needs of the present and prepares students to meet their future learning needs” (p. 151). Furthermore, sustainable assessment creates learners who are more able to cope with the changes they will experience in their working life (Boud & Soler, 2016). Adaptability is especially critical for graduate engineers, who must quickly come to terms with and continuously stay abreast of rapid and frequent change in the sciences and technologies which underpin their field (Engineers Australia 2013).

Unlike many commonly used higher education assessment genres (e.g., exams, traditional essays), which are primarily used to measure learning, sustainable assessment tasks become learning pathways for students to develop intricate knowledge, skills, and dispositions. Developing and implementing such sophisticated assessment is challenging for institutions with a range of study modes (online, blended, and on-campus) and diverse students who vary widely in demographic characteristics such as age, socio-economic status, and ethnicity. Furthermore, sustainable assessment should have real-world currency and encourage students to develop lifelong learning skills and self-regulatory competence to perform in complex and rapidly evolving environments.

To develop these skills, students must often engage with pedagogies and assessment genres they may not have previously encountered. Project-based learning contextualises the curriculum via inquiry around complex and current project scenarios and is often assessed through portfolio assessment, self- and peer-assessment and in some cases, reflective writing. These assessment genres, implemented effectively, can foster lifelong learning and self-regulatory competence.

The use of project-based learning and novel forms of assessment is not new to engineering education but students can react negatively on their initial encounter when they are placed outside of their comfort zone, or they do not understand what to do to be successful (Struyven & Devesa, 2016).

The study aimed to develop effective scaffolding and support for introducing portfolio assessment to first-year engineering students in response to student voice data. It was thought that portfolio assessment would provide students with a sustainable assessment experience that would help them develop not only engineering content knowledge and skills, but also improve their self-regulation and abilities to act as self-directed learners.

Methodology

The study reported here was part of the larger Higher Education Participation and Partnerships Programme (HEPPP) funded Supporting Student Assessment Success (SSAS) Project (Dargusch & Harris, 2015-2017), investigating students’ perceptions of the assessment supports provided in first-year university courses. Ethical clearance was obtained (H15/02-024) to gather data on student experiences of assessment supports within the unit. All data were collected by the second and third authors who were not involved in teaching into the unit.

An action research approach was adopted to examine implementation of portfolio assessment in a project-based learning core unit (ENEG11001 – Engineering Skills 1, superseded in 2016 by ENEG11005 – Fundamental of Professional Engineering) offered to first-year students in several engineering courses at CQUniversity. Data for this paper were primarily collected via the university higher education dashboard and student surveys. Students were provided details of the study and ethical safeguards, giving consent by choosing to complete the instrument. Students’ value perceptions were obtained from the 2015 cohort by 42 participants representing a 27% response rate. In 2017, 37 participants returned valid surveys representing a 26% response rate. Participants were asked to rate assessments on a six-point scale in terms the 'value' of their learning, how much 'effort' was required to complete them and how 'difficult' they were.

Several interventions were conducted with the aim of better preparing students for portfolio assessment. Feedback from staff and students were used to make improvements to the unit (Table 1). Interventions were implemented over the 2016 and 2107 offerings of ENEG11005.

Table 1: Interventions to assessments and supports

2015	2016	2017
Portfolio Assessment: 100% Individual Portfolio due in Exam Week. Comprising Grade Nomination (self-assessment against the marking rubric), Personal Reflective Journal, Individual Workbook, Individual Reflective Paper (encouraged to submit early to obtain formative feedback by Week 6), Individual Drawing Folder (formative feedback offered in Week 9), Self and Peer Assessment results, and a Viva Voce. **Other Assessment:** Four team projects with formative technical reports or presentation to create scenarios for students to compile evidence in their portfolio of meeting the marking rubric and unit learning outcomes. **Assessment Supports:** • Reflective writing guide • Referencing guide • Basic examples of Grade Nominations and entries in Workbooks and Reflective Journals • Portfolio Marking Rubric • Technical Report Template	**Portfolio Assessment:** 30% Individual Portfolio due in Exam Week similar to 2015 but without Reflective Paper and Drawing Folder to allow separate assessments which scaffold skills for creating the portfolio. **Other Assessments:** 10% Individual Reflective Paper due in Week 4, to scaffold reflective writing. 30% Individual Sketching and new AutoCAD drawing activities due in Week 7, to scaffold the development of technical skills for the team project. 30% Project Action Plan and Individual Reflective Paper due in Week 9 to prepare students for addressing the portfolio marking rubric. One team project with formative technical report and presentation, in response to students' requests to limit the number of project investigations. **Assessment Supports:** • As with 2015 plus … • Instructional videos for drawings activities as they are highly valued by students (Taylor, Harris, and Dargusch 2015) and they flip the classroom making assessments a learning pathway (Brown 2005). • Reflective Paper exemplar	**Portfolio Assessment:** As with 2016 but Viva Voce removed because it required substantial staff effort, yet had limited value by students (Taylor, Harris, and Dargusch 2015). **Other Assessments:** As with 2016 but second reflective paper replaced with a summative Team Technical Report in response to student feedback regarding excessive assessment on individual reflection and not enough emphasis on team project outcomes. This structure promotes completing all aspects of the team project to ensure adequate evidence is obtained for addressing the portfolio marking rubric. **Assessment Supports:** • As with 2016 plus … • Portfolio exemplar as students requested additional exemplars when queried on how unit resources could be improved (Taylor, Harris, and Dargusch 2017). • Additional instructional videos comprising preparing the report introduction, locating data sources and performing a literature search, and completing several technical tasks for the team project and individual portfolio.

Also in 2017, to help students perceive the importance of mastering skills being taught at the foundation level, a framework was introduced for progressive development of professional skills based on critical aspects of employability for engineers (Nair, Patil & Mertova 2009; Trevelyan 2014; Willmot & Colman 2016; Dowling et al. 2016).

Results and Discussion

Results are presented by comparisons over the three-year period to 2017 being offerings of ENEG11001 – Engineering Skills 1 in 2015 superseded by ENEG11005 – Fundamental of Professional Engineering in 2016. Key areas analysed include student satisfaction; unit grade distribution; and students' perceptions of assessment task 'value' to their learning, how much 'effort' was required to complete them and how 'difficult' they were to complete.

Student Satisfaction

The response rate for the student satisfaction surveys over the three years remains reasonably constant (approximately 60%), indicating that comparisons between the cohorts can be made and that in these units, the students remained reasonably engaged (Figure 1).

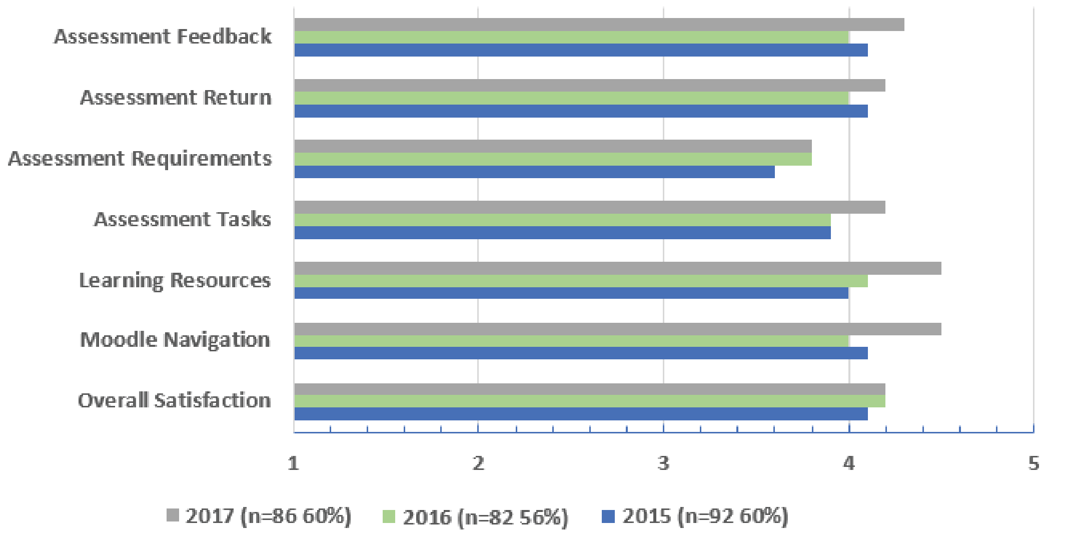

Figure 1: Student satisfaction trends in ENEG11001 (2015) & ENEG11005 (2016 & 17)

The 2017 offering achieved or equalled the highest student satisfaction across all key performance areas, suggesting that the interventions have overall achieved a positive outcome for the students' experience and satisfaction.

The satisfaction score for assessment requirements remains consistently below the university average despite focus by the teaching team on thoroughly introducing and preparing students for the assessment (Portfolio, Reflective Paper, Self-and Peer Assessments). This result confirms reports in the literature that students may react negatively to new forms of assessment (Struyven & Devesa, 2016).

Assessment tasks, learning resources and Moodle navigation (Web-based learning management software) all show significant improvements in student satisfaction. Interventions which focused on improving these aspects of the unit appear to have been successful; it appears that having a structured approach to introducing assessment was appreciated by the students.

Grade Distribution

Minimal changes were made to the standard, type and level of assessments over this period, yet the grade point average has been steadily increasing with more students now able to achieve exceptional results and higher attainment of the unit learning outcomes (Figure 2). This indicates the approaches used to introduce new assessments may effectively reduce the negative reactions to first encounters of foreign assessment types, at least in relation to student grade concerns.

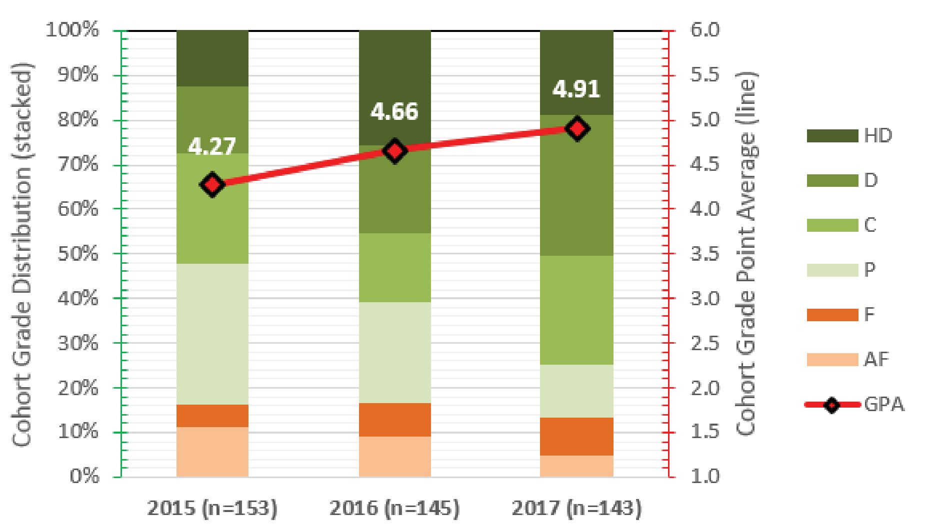

Figure 2: Grade trends in ENEG11001 (2015) & ENEG11005 (2016 & 17)

Student numbers are slightly reducing in line with current trends in engineering enrolments across Queensland. An increasing completion rate has enabled the number of students passing the unit to be maintained.

Absent Fail grades are steadily decreasing, suggesting that students are increasingly feeling capable of attempting these forms of assessment. Managing attrition at CQUniversity is challenging owing to servicing regional centres in Queensland which have some of Australia's highest representations of students with low socio-economic status. Furthermore, many students are the first in their family to higher education, and/or of Aboriginal or Torres Strait Islander descent. Considering this context, these interventions have achieved encouraging results for student retention.

In 2017, 75% of students achieved a grade of Credit or higher suggesting the new methods of introducing assessments and other interventions are allowing most students to achieve good results and to accomplish the unit learning outcomes confidently.

Students' perceptions of value, effort and difficulty of assessment tasks

The range in task value perceptions of students analysed in the 2015 and 2017 offerings is very similar with upper and lower means approximately at 4.1 and 5.2, where 'Moderately Valuable' was coded 4.0 and 'Valuable' was coded 5.0 (Figure 3). This consistency suggests that direct comparisons of task value rankings between the two cohorts could provide an insight into changes in students' perceptions of assessment tasks resulting from the interventions.

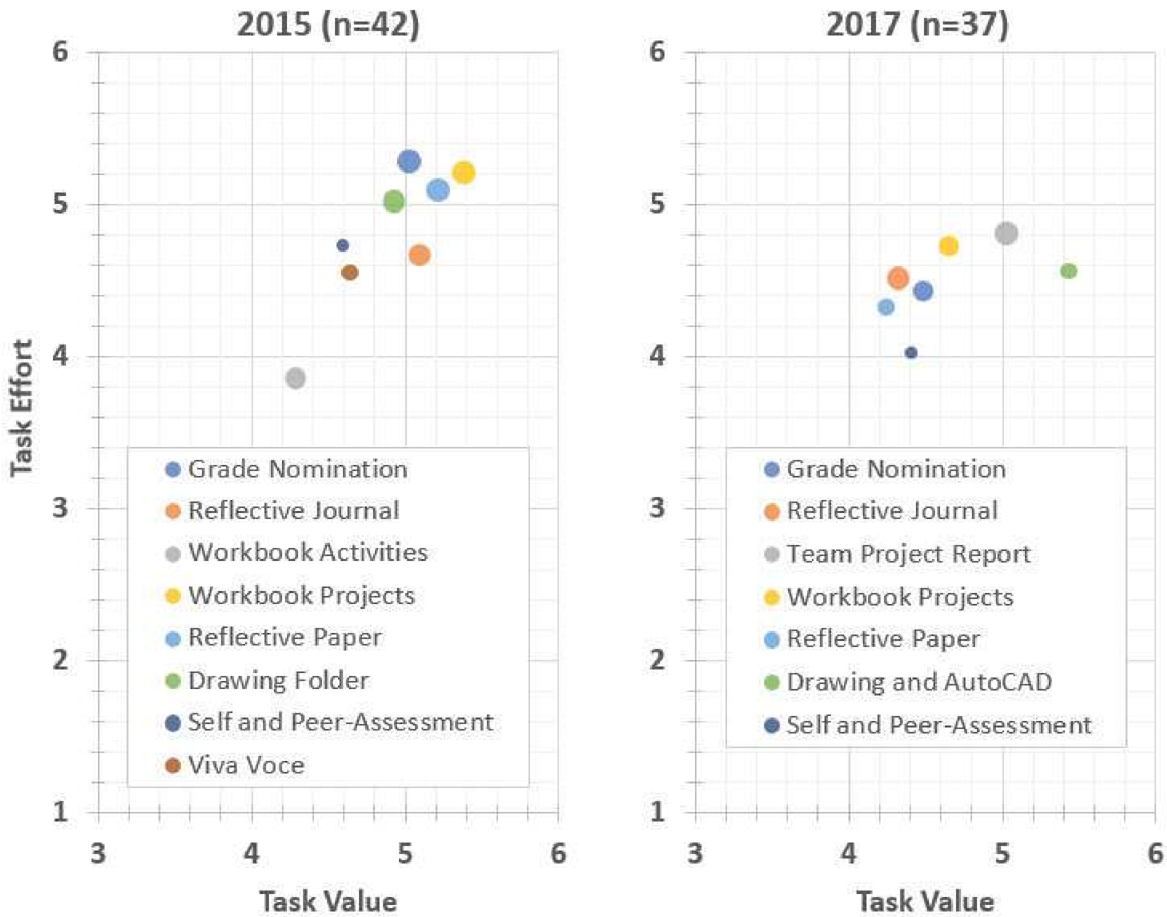

Figure 3: Students' perceptions of task value, effort and difficulty (denoted by marker size)

The 2017 cohort thought assessment tasks required less effort to complete but, as stated earlier, this cohort also achieved a higher grade point average. This is consistent with indicators that task difficulty also reduced marginally in 2017 (Figure 3). The reduction in effort by students was intentional as interventions included better preparing students for the assessments and reducing the number of projects. Enabling students to achieve higher grades with less effort has introduced learning efficiencies, and has also reduced instructor workloads with fewer projects to facilitate and responses needed for assessment queries and to correct students' misconceptions.

Replacing some freehand sketching activities with AutoCAD tasks has made the drawing assessment the most valuable to students by directly developing skills for their team project and portfolio, where previously it was moderately valuable by comparison to other assessments. The task is now also perceived to be easier through scaffolding with instructional videos which enables students to learn through completing the assessment. Many encouraging comments were received from the students: *"I found the videos extremely helpful as I learn well visually. Being able to rewind and watch again was very helpful."* The change in student perception of this task is a positive indication of benefits that can be achieved through a structured approach to introducing portfolio assessment where suitable resources support students through the learning opportunities.

Replacing the second reflective paper and activities from the textbook with a new summative assessment of a Team Project Technical Report (30%) made this task significantly more valuable to students' learning and marginally more difficult to complete, requiring students to apply a lot more effort. This is a positive change as preparation of technical reports and working with peers are essential skills that are also now progressively developed using a whole-of-course approach following suggested practices for sustainable assessment. This intervention also allowed students to create many suitable entries for their Portfolio Workbook and to unpack learning scenarios in their Reflective Journal, thus creating a structured approach to introduce the Portfolio assessment. The new iteration of the unit should also prepare students very well for further units that focus on developing these professional skills.

Reducing the portfolio to 30% resulted in a moderate reduction in value, effort and difficulty for the grade nomination (a self-assessment of their Portfolio and nomination of what grade students believe they have achieved against the marking rubric). This result was mostly as intended. The grade nomination should be perceived as an assessment support tool which provides clear instructions for efficiently completing portfolio assessment to their desired level of achievement. Thus, the intentions were to reduce the effort needed and difficulty with the tasks but not to reduce its perceived value towards their learning. Greater emphasis might be needed to link the portfolio activities back to the unit learning outcomes and hence enable students to comprehend that they are beginning their development of skills expected in engineering practice.

Reducing the number of reflective journal entries in response to student feedback (15 down from 25) has devalued the reflective journal task but not significantly reduced the effort required or difficulty. This is not a positive change. Instilling reflective practice is essential for engineering graduates and learning through self-assessing and reflection is a key part of sustainable assessment. As with the Grade Nomination, more emphasis on the link with professional practice might be necessary to increase the perceived value of this task.

The perceived value, effort, and difficulty of the Workbook has reduced by separately assessing the Team Report. This is believed to be a transfer of value perceptions from individual tasks to team-based tasks which is a positive outcome for building professional skills and attaining the unit learning outcomes.

Changing the topic of the reflective paper from 'the history of engineering practice' to 'transitioning to higher education' and making this task a separate summative assessment (10%) has significantly devalued the task and reduced the effort and difficulty. This is also not a positive change. Without a longitudinal study, it is impossible to measure whether the new topic will better prepare students for their future learning needs. Also, without further questioning of students, it is unknown what impact assigning a low summative percentage had on students’ perceptions. If something is not highly valued, it is likely to be easily forgotten, which works against the objectives of sustainable assessment.

Self and peer-assessment remained of similar value to the students but required much less effort in 2017. The only change to this assessment was to encourage teams to establish a self and peer-assessment grading rubric as part of their Portfolio assessment. It appears that this has helped students to complete the task allowing them more time to devote to other activities.

Conclusions

Several interventions were developed to better prepare students for new forms of assessment such as portfolios, reflective papers and self and peer assessment in a first-year engineering unit. Student satisfaction and grades were analysed over a three-year period to 2017, along with student surveys and interviews to establish students’ perceptions of assessment task ‘value’ to their learning, how much ‘effort’ was required to complete them and how ‘difficult’ they were to complete. It is important to note that relatively low sample sizes were studied providing anecdotal evidence of improvements in the student experience.

These data suggest that not only could students see the benefit of a structured approach to introducing assessment, but that introducing sustainable assessment can potentially improve the student experience and academic results. Student satisfaction increased across nearly all performance areas. More students attempted assessments, completed the unit, and achieved excellent grades.

Most interventions resulted in a positive impact on students' perceptions of assessment tasks. Introduction of instructional videos, AutoCAD activities and a summative assessment on the Team Project Report was well received by students and created learning pathways, giving students insight into their future learning needs, and skills in self-assessment, self-direction and working with their peers.

Further work remains to increase value perceptions of preparing a portfolio grade nomination, a reflective journal and a reflective paper, all of which are essential skills for practising engineers and key components of sustainable assessment.

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Constructivist Simulations for Path Search Algorithms

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SESSION

C1: Integration of Theory and Practice in the Learning and Teaching Process

CONTEXT We have augmented a large Artificial Intelligence course with a blended learning component, using a social constructivist cloud-based learning platform. This afforded the opportunity to redesign the course delivery by using a flipped tutorial approach where students engage in online activities and interactions which are then consolidated in a face-to-face tutorial. The main focus of this paper is a maze widget which was developed for learning about path search algorithms as part of these online activities.

PURPOSE To create a widget that would offer both constructive and interactive learning experiences in order to help students better conceptualize and understand the relative strengths and weaknesses of nine different path search algorithms.

APPROACH The maze widget allowed students to step through and visualize an algorithm selected from a drop-down menu on randomly generated mazes, as well as creating their own mazes using an online editing tool, and posting them to online galleries where students could view, comment upon, and interact with submissions from other students. Qualitative student feedback was collected to gauge the extent to which this maze widget helped students with learning path search algorithms.

RESULTS Students posted a great variety of mazes to the gallery and wrote descriptions which seem to indicate not only a deeper understanding of the material than was previously possible, but also a better student learning experience.

CONCLUSIONS We found that a carefully designed interactive widget can help students to learn a challenging topic through exploration and interaction, and reach a deeper understanding of the fundamental concepts. A collaborative and iterative course design process informed by educational theory can lead to innovative approaches in engineering education, which make learning experiences more engaging and effective.

KEYWORDS Path Search Algorithms, Constructivist Simulations, ICAP Framework

Introduction

This paper describes our experiences in the redesign of a large Artificial Intelligence course, including migration from face-to-face delivery to blended learning with flipped tutorials. We include background and motivation, some of the innovations we introduced, general observations about student experience, and a detailed description of a maze widget which we developed to help students learn about path search algorithms.

Collaborative Course Design and Development

We recently undertook to redesign a large Artificial Intelligence course at UNSW – motivated by the need to accommodate a significant increase in student enrolments, as well as a desire to enhance the educational experience with online materials, innovative presentation and specially designed widgets. Funding support was obtained through a new University initiative to explore digital uplift through collaboration with external education technology providers. In our case, the technology provider was OpenLearning, a cloud-based social constructivist learning platform with a focus on activity-centered learning in a student-centered online collaborative learning environment.

An academic who had been teaching the course for a number of years in a more traditional face-to-face format acted as subject matter expert (SME), and collaborated on all aspects of the course redesign and delivery with an instructional designer (ID) from OpenLearning who was pursuing postgraduate studies in the learning sciences. The maze widget was created by a software engineer (SE) from OpenLearning with feedback and guidance from the SME. The SE, who was a student in the SME's course some years earlier, had course design experience, a theoretical background in education, and expertise in artificial intelligence.

The team collaborated remotely to contribute content, design, coding and development of the course, using tools such as Slack, Google Drive and the online learning platform itself, which were chosen for being both easy to learn and effective at supporting collaboration. The SME and ID met weekly over several months to plan, co-develop, and finalize course design and content, while the SE advised on technical issues and worked intensively on the maze widget.

Blended Learning with Flipped Tutorials

In total, 260 undergraduate and 300 postgraduate students were enrolled in the course. There was great diversity among these students in regard to prior study, coding experience, relevant general knowledge and socio-cultural background. In order to meet the needs of such a large and diverse group of students, and keep them engaged and motivated, we designed a blended learning model which expanded upon the existing slide decks and lecture recordings with short tablet-style walkthrough videos, links to extension material, and online activities that formed a flipped tutorial model.

Lectures were scheduled on Thursday evenings, and the material from each lecture was consolidated in smaller "flipped" tutorial groups (problem sections) of 25 students, which were all scheduled on Thursday or Friday of the following week. Course content was released in advance of the lecture in the form of text, images and short explanatory videos. Students were expected to work through a number of online activities in the collaborative learning platform during the week between each lecture and the corresponding tutorial.

The general idea of the flipped classroom is to use technology to introduce content in advance, in order to free up class time for an expanded range of learning activities (Roehl et al., 2013). In consideration of the large class size, we developed a *flipped tutorial* approach in which students are introduced to the content during the lectures, develop their understanding through online activities and interactions during the week, and consolidate their understanding of the material through smaller group discussions and reflection in the face-to-face tutorials at the end of the week. In addition to the tutors (teaching assistants), an online facilitator (who was a former student in the course) was recruited to create social presence and support/guide learners as they progressed through the course.

Path Search Algorithms

One theme that is fundamental in many areas of engineering education is the interplay between algorithms and problem instances. A variety of competing algorithms or techniques are presented for solving a certain class of problems; but, some of these algorithms may be better suited than others to a particular situation, depending on certain attributes of the problem instance. In this paper we particularly focus on path search algorithms. The students are first introduced to these algorithms in Weeks 3 and 4 of our course, and the algorithms are demonstrated by tracing through examples from the textbook (Russell & Norvig, 2016) which involve finding a path between specified cities in a map of Romania. Students are then expected to apply the same algorithms to more complex domains such as solving a 4-by-4 sliding tile puzzle. In previous offerings of the course, a typical tutorial question might be: “Describe a search space in which breadth-first-search performs much worse than depth-first-search”. However, we found that students were generally unable to come up with their own answers to this type of question; and, even when told an answer by the tutor, they still had difficulty conceptualizing the relative strengths and weaknesses of the various algorithms.

Traditional textbook instruction is limited as it can contain knowledge that is decontextualized and explicit. Beyond simply delivering an exposition of each algorithm, we felt that students would gain a deeper understanding if they were able to create their own problem instances, apply the various algorithms, and explore for themselves why certain kinds of test cases would cause one algorithm to perform particularly well, while another may consume excess time or memory, or produce a poor quality solution. Simulations were chosen as a tool because they allow knowledge to be experienced contextually, so implicit domain knowledge is learned, which “will foster deeper understanding and make the information more accessible in appropriate problem-solving contexts” (Taylor & Chi, 2006).

We therefore designed a purpose-built maze widget to support the online activities for Weeks 3 and 4 of the course – which covered Uninformed and Heuristic Path Search Algorithms, respectively. The aim of the widget is to facilitate conceptualization of the algorithms and exploration of the interplay between algorithms and problem instances, thus bridging the gap between simple examples that can be worked through by hand, and complex domains which are too large or multi-dimensional to be directly visualized. This approach builds upon the observation that “the move from a static model in an inert medium, like a drawing, to dynamic models in interactive media that provide visualization and analytic tools is profoundly changing the nature of inquiry in mathematics and science” (Brown et al., 1999).

Maze Widget

The maze widget allows students to generate a grid maze and then select from nine different path search algorithms, of which five are uninformed (depth-first, breadth-first, iterative deepening, cost-directed, and bi-directional cost-directed searches) and four are heuristic or “informed” search algorithms (Greedy, A-star, iterative-deepening A-star, and bi-directional

A-star). For the heuristic search algorithms, students can additionally choose between two different heuristics (Euclidean distance and Manhattan distance). The widget was implemented in a flexible way which allowed the algorithms to be introduced over two separate activities within the course – the first to introduce the uninformed searches, and the second to build upon those concepts with the heuristic searches.

The widget code was written for the Web in ES6, and included implementations of each of the algorithms. The implementation allows students to run the algorithm at varying speeds, or step through one line at a time, so the algorithm can be visualized for immediate reflection. Pseudocode for the selected algorithm is displayed alongside the simulation, thus allowing the student to easily follow the logic of the algorithm as each step is executed and displayed by the simulator.

The widget design went through three main iterations. The first conceptualized its use as a visualization tool. Students would first be asked to select a certain style of maze (tree maze, graph maze, concentric tree maze, concentric graph maze, alternating squares or empty) from a drop-down menu, and then press a button to generate a random maze in the specified style (Figure 1). They could then select an algorithm from another drop-down menu and step through the algorithm, or let it play out automatically – with a speed control. This would provide students with immediate reflection on how the algorithms execute within the grid-maze, and an opportunity to compare and contrast the different approaches.

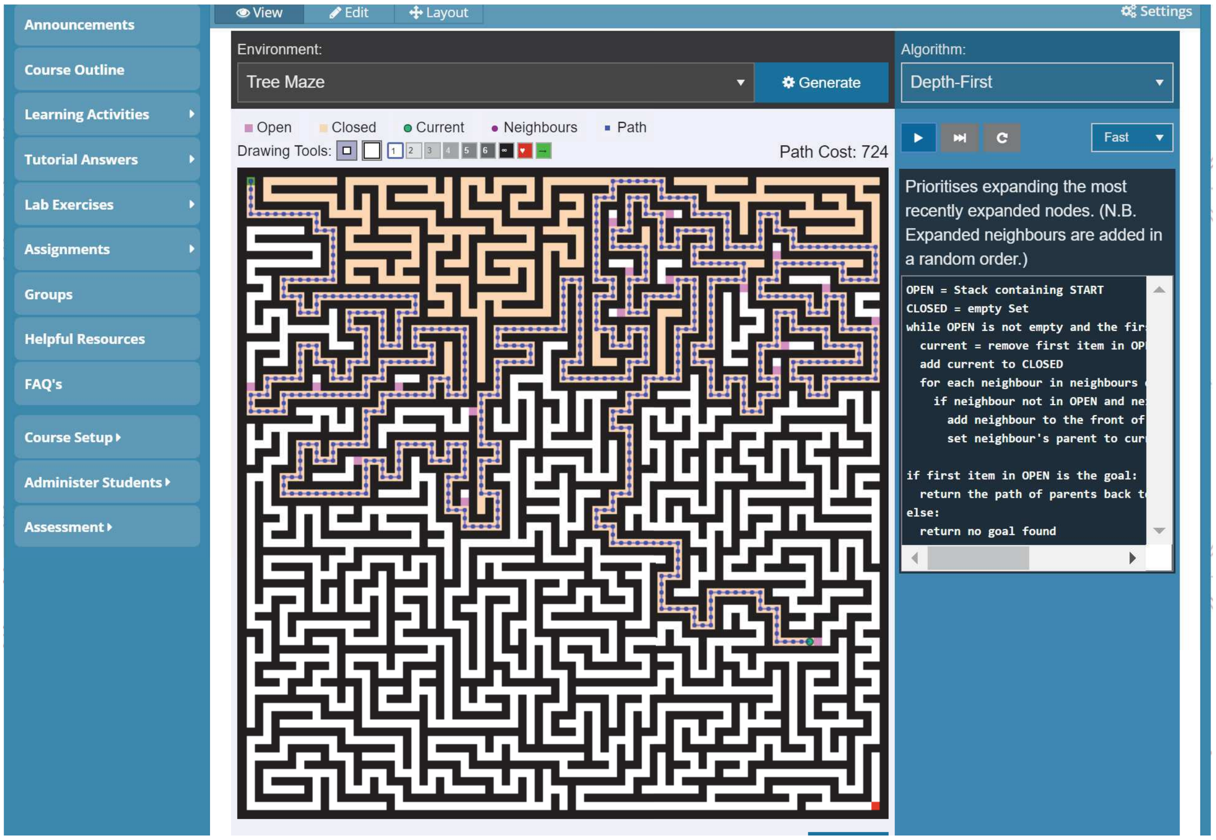

Figure 1: Maze widget simulating a depth-first search on a randomly generated maze

A second iteration of the design enabled active and constructive experimentation. The widget was augmented with maze editing functionality, using an interface which is similar to a simple 'paint' program. By selecting colours from a palette, the student could move the start location (green), add one or more goal locations (red) or "paint" the maze with obstacles (black) or empty spaces (white). This allowed for more open-ended exploration of path search algorithms which afforded a more constructive learning experience. Students could actively explore and experiment, and by reflectively analyzing the resulting behaviour of the simulation, build analogies/schemas/concepts for how each algorithm behaved in customized test cases, and how to construct situations which illustrated the strengths and weaknesses of each search algorithm.

The purpose of the third iteration was to promote and enable a community of sharing. The widget was further augmented to allow the sharing of student-created mazes (Figure 2). This also included the ability to tie into the platform's social sharing tools to share and showcase different scenarios, enabling students to experiment with and further modify each other's creations in simulation, with the opportunity for community feedback and commentary.

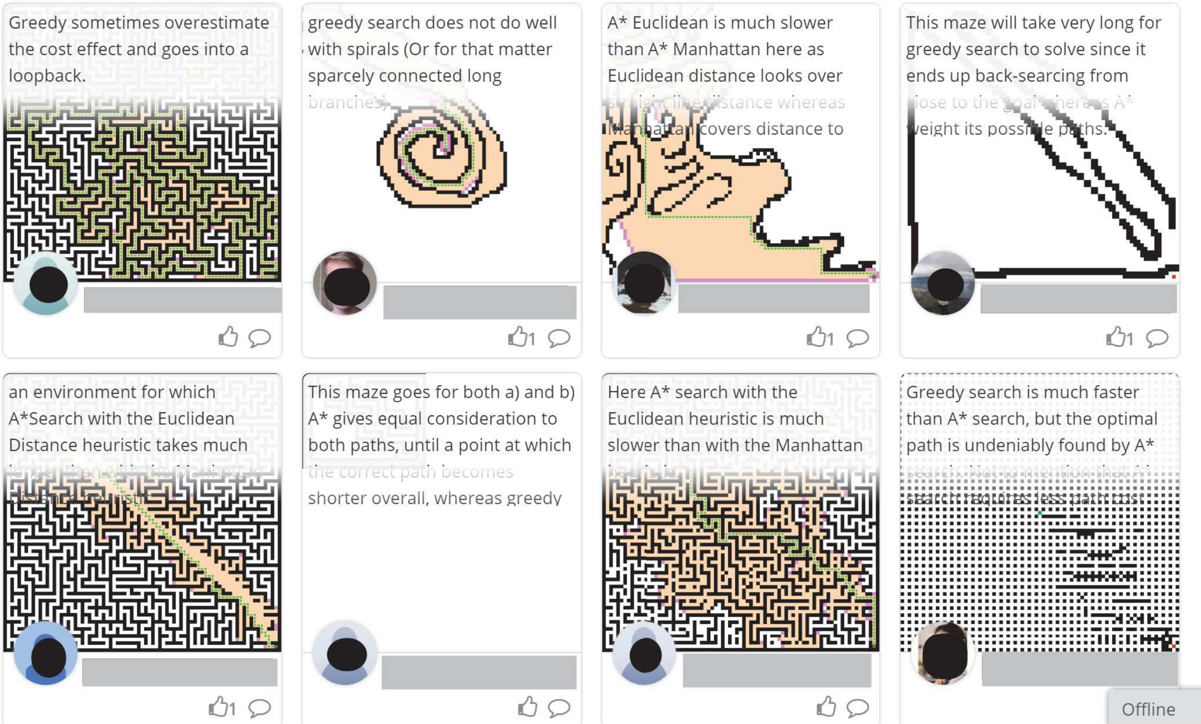

Figure 2: Gallery view of student-created mazes and interactions

Activities and Discussion Points

Students were encouraged to work through online activities and discuss their findings both on-line and in the face-to-face tutorials at the end of the week. Discussion points for the flipped tutorial on Uninformed Path Search Algorithms (Week 3) included:

- Compare the speed of Depth First Search (DFS) and Breadth First Search (BFS) on random tree mazes and concentric graph mazes
- Create a maze for which BFS finds a solution considerably faster than DFS
- Create a maze for which DFS finds a solution considerably faster than BFS
- Create a maze for which bi-directional search is faster than BFS
- Run Iterative Deepening Search (IDS) on a random maze and explain why it is slow
- For what type of problem (not a maze) would IDS be faster than BSF and DFS?

Discussion points for the tutorial on Heuristic Path Search Algorithms (Week 4) included:

- Create a maze for which Greedy Search takes much longer than A*Search
- Create a maze for which Greedy Search produces a path that is much longer than the optimal path
- Create a maze for which A*Search with the Euclidean distance heuristic takes much longer than with the Manhattan distance heuristic
- Create a maze that is interesting for some other reason

Pedagogical Approach

The OpenLearning platform provided the design team the opportunity to augment the traditional lecture approach, and to provide opportunities for more engaging and collaborative learning experiences. The design team used the ICAP framework (Chi & Wylie, 2014) to provide a guideline for the activities we adapted for the flipped tutorial model. The ICAP hypothesis posits that “engagement behaviors can be categorized and differentiated into one of four modes: Interactive, Constructive, Active, and Passive. The ICAP hypothesis predicts that as students become more engaged with the learning materials, from passive to active to constructive to interactive, their learning will increase” (Wiggins et al., 2017). This has been proven to be effective in engineering education (Menekse et al., 2013), and was central to the development of our maze widget, which in addition to helping students visualize and contextualise path search algorithms, provided opportunities for constructive and interactive learning experiences.

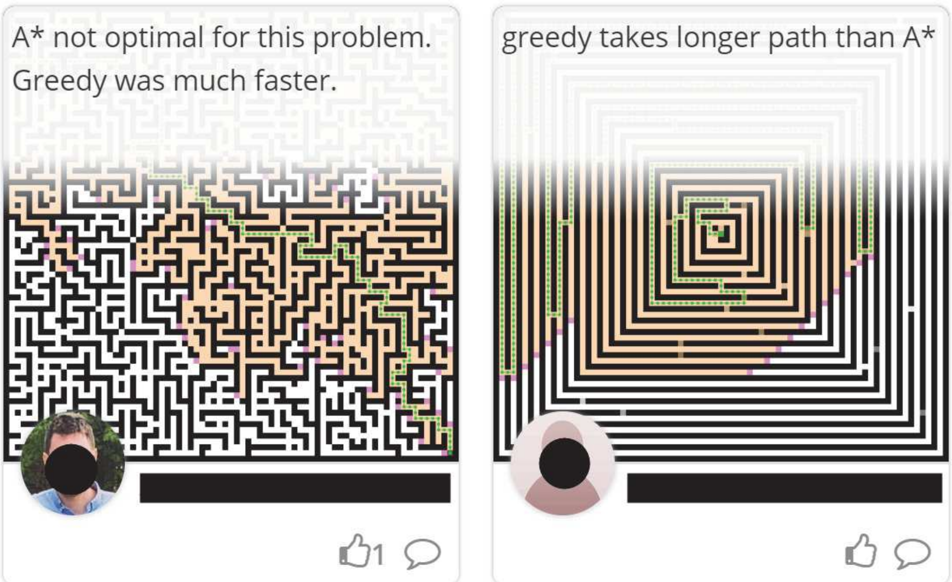

Figure 3: Students sharing mazes which illustrate the relative strengths and weaknesses of Greedy Search and A* Search

The functionality of the maze widget allows students to explore the same algorithm on different kinds of problem instances (Figure 3) allowing for analogical encoding by drawing a comparison across examples (Gertner et al., 2003) thus leading to a deeper understanding of the algorithms.

Student Feedback

Even though it was only a formative task for group discussion and self-evaluation, the maze widget activities proved to be very popular with the students, with many students making multiple contributions and insightful comments.

Our findings from observing the student contributions on the platform, coupled with the qualitative student feedback supports the finding in (Menekse et al., 2013) that “the ICAP hypothesis provides a comprehensive methodology to create and design materials and activities that will promote effective learning in engineering classrooms”.

Figure 3: Students sharing mazes which illustrate the relative strengths and weaknesses of Greedy Search and A* Search

Qualitative feedback was incorporated into a reflection page at the end of each module. Following the first use of the Maze widget in week 3, Uninformed Path Search, students were given an opportunity to provide any insights about the blended module. The results show that students benefited from the visualization of the maze widget, and the widget helped students gain a deeper conceptual and practical understanding of the algorithms.

Across all comments on the platform, there was a lot of feedback on the maze widgets, and all of it was positive. Voluntary feedback from students included:

> “The maze search widget was helpful in learning about search strategies, I really enjoyed seeing how the algorithms work.”
>
> “This week's activities gave me a more clear idea about how Breadth First Search and Depth First Search perform in different types of mazes. It was something I had a brief idea about but never visualised it.”
>
> “I enjoyed to maze widget – it’s a really great representation of all the different algorithms and really helped to solidify my understanding!”
>
> “the maze apps makes learning it more interactive less theoretical”
>
> “I thought the maze app was a brilliant piece of kit, well done guys.”

A deeper understanding of specific path search strategies gained by students interacting with the maze widget can be seen in the following student comments:

> "This week I enjoyed further studying search algorithms, and learnt quite a lot about depth-first search. Primarily derived from it drunkenly wandering about the maze field."

> "I did not enjoy having to watch the maze-solving widget run using different search algorithms – sometimes it was frustrating seeing how close the algorithm was to the solution but how long it was taking to actually find it (of course this ultimately provides helpful insight into each algorithm)!!"

Feedback from another student illustrates how the maze widget helped to further develop a practical understanding of a search algorithm:

> "The Romania problem has helped me to understand different uninformed search strategies. The maze search widget gave me a better insight of how uninformed searches are linked to the real world."

Another student provided feedback that identifies the strengths of using a simulation to visualize algorithms over traditional teaching approaches:

> "I felt that I learnt a lot in regards to search patterns – really wished I did this course with COMP1927 – was so lost during it –> this is by far amazing! :D"

Overall, we found that the OpenLearning platform, and specifically the maze widget simulation are very well-suited for engineering education. The social constructivist platform created opportunities for students to learn collaboratively, and the qualitative feedback from the students indicates that the maze widget helped students to visualize, conceptualize, and understand how to apply the algorithms.

Next Steps

An iterative approach has been taken to the maze widget design, and to the overall course design as well. Quantitative data from the course analytics has been analyzed, and qualitative feedback from students has been reviewed. Reflections on the design included some technical adaptations, as well as providing more student control, better use of the online tutorial group function, and the inclusion of some more tablet-style walkthrough videos for difficult technical components of the course. There are plans to make the maze widget available outside of the course, and the design team may experiment with a productive failure approach (Kapur, 2012) outside of the course, and potentially adapt sequencing based on what is learned.

The success of the blended learning and flipped tutorial approach has led us to consider modifying the course so it can stand alone as an online offering. It should be noted that this would still require an online presence for the lecturer and chosen course facilitators. We also plan to gather more qualitative and quantitative data around the final assignment, designed by the SE together with feedback and guidance from the SME, which required students to apply their knowledge of path search algorithms gained from the maze widget to solve a game-based 'Adventure Land' scenario.

Conclusion

Our experiences supported the use of the ICAP framework, which "can provide specific guidelines for how to create lessons that incorporate overt behaviors that are associated with higher levels of engagement and their associated knowledge-change processes" (Chi & Wylie, 2014) and we suggest that it is a useful tool for appraising course design and delivery.

Simulations like the maze widget could potentially be applied in any area involving the interplay between algorithms and problem instances. Potential applications include: sorting, storage & retrieval, graph and tree algorithms, string & text processing, machine learning, constraint satisfaction, game theory, data compression, signal and image processing, circuit design, network routing and switching, and cryptography.

Our collaborative and innovative design process highlighted integration in engineering on multiple levels – academic and industry, teacher and (former) student, theory and practice – thus illustrating how an engineering approach to education can make learning experiences more engaging and effective.

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Inclusive engineering education: making engineering degree work for more students

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CONTEXT

In an increasingly interconnected and rapidly changing world, the role of vibrant, creative and diverse engineering workforce is critical. To contribute to technological advancements, engage in global collaboration, solve complex problems, encourage a more social and leadership skill, it is necessary for the future engineers to be more diverse in its racial, gender, and socioeconomic representation. Many Australian universities followed the recent government objectives aimed to increase participation in Higher Education (HE) and created the courses and programmes providing alternative pathways to HE for students from non-traditional, mature students and low socioeconomic status (SES) backgrounds. However, the majority of non-traditional students select non-engineering courses as the option of university pathway.

PURPOSE

This study focused on research of student's commitments during their study at the Western Sydney University, The College together with an example of successful development and integration of Social Media project (YouTube Channel) to the first year engineering curriculum.

APPROACH

The quantitative data were collected from three engineering courses: Standard Diploma in Engineering, Extended Diploma in Engineering and Associate Degree in Engineering (online course). The analysis of student's workload was conducted from the student's diaries where students recorded the time they spend on the different activities during the week. The analysis of YouTube Channel created for the first year engineering students was conducted according to the number of views, audience retention, number of shares and comments.

RESULTS

This study demonstrated that the students from the university pathway programs, such as the Diploma and Extended Diploma in Engineering are required to spend significant amounts of time which is not directly linked to their studies, such as part-time job, care responsibilities and travel time. To increase student's engagement and learning performance in engineering academic pathway program a multimedia Project in the form of YouTube Channel was created and integrated into the first year engineering subject curriculum. Created videos received very positive feedback from students which also led to the improved unit assessment results and demonstrated the strong interest with the wider engineering community.

KEYWORDS
Engineering pathway, non-traditional students, social media, YouTube

Introduction

Throughout the developed world, including Australia, policies aimed at widening participation in higher education (HE) are increasingly being implemented to improve the quality of the national workforce (Carpenter, Dearlove, & Marland, 2015). In Australia, this policy agenda has been driven by the Review of Australian higher education (Brooks, 2004) which has set a target to increase the intake of students so that a larger proportion of the population will hold an undergraduate degree by 2020. There has been progress in this regard in Australia proved by the increased rate of higher education participation over the past decade for individuals from disadvantaged backgrounds (Li, et al, 2017).

While more students from low socioeconomic status (low-SES) enrolling at the university, it is also well recognised (Steinberg & Monahan, 2007) that students from a low-SES group are in general less prepared to fit into the university system.

Students from low SES backgrounds often have complex lives and competing priorities. Many of these students required to have a job and many have other caring responsibilities. They must balance academic study with these caring and related responsibilities, which often include the need to engage in paid employment while studying.

For that reason, some innovative approaches in high education found to be quite effective, especially for the students from low-SES. Social Media is well known as an effective “problem-solving tool”. When people have a question one strategy they can use to get an answer is friendsourcing - broadcasting the question to one or more of their social networks. For example, people can post a question via a status update on Facebook, share interesting YouTube videos or send a message to a group chat on a messaging app (Khojasteh, et al, 2017). A similar effect was observed in education, where Social Media was well recognised for providing students and educators socially engaged educational experiences with unsupervised and informal tools and spaces where authentic learning occurs (Oliveiar, et al, 2017).

This study focused on research of student’s commitments during their first year engineering study at the Western Sydney University (WSU), The College together with an example of successful development and integration of Social Media project (YouTube Channel) to the first year engineering courses.

The study of student’s workload in the university pathway programs

The analysis of student’s workload was conducted from the student’s diaries where students recorded the time they spend on the different activities during the week: from Monday to Sunday. The quantitative data were collected at the WSU, the College from three engineering courses: Standard Diploma in Engineering, Extended Diploma in Engineering and Associate Degree in Engineering (online course). Successful completion of the Diploma courses grants student entry into the second year of study in the Bachelor Degrees in Engineering at the Western Sydney University. The data was collected during week 4 in the Second Term of the Diploma Programs and during week 5 in the Quarter 3 of the Associate Degree Program.

The total of 109 students agreed to participate in the study.

The parameters of each course are summarised in Table 1.

Table 1

Program	Mode of delivery	Entry requirements	Length of study	Number of students participated in the study
Standard Diploma	Face-to-face	ATAR 50	12 months, full time	35
Extended Diploma	Face-to-face	Open access	16 months, full time	53
Associate Degree	Online	3-year industry experience	4 years, part time	21

As a first step in data analysis from the students' diaries, we excluded data of students who did not complete any parts of the questionnaires. In addition, the data were evaluated for irregularities. Specifically, we looked for anyone who responded to each survey item with the same answers (e.g., marked "0" for all time spend for the face-to face study).

To understand and compare student's commitments during the weekdays and the weekend, the total number of hours students spend for each activity was calculated from Monday to Friday and from Saturday to Sunday separately. The summary of the student's commitments as average hours during the weekday and the weekend for three programs – Standard Diploma in Engineering, Extended Diploma in Engineering and Associate Degree in Engineering are shown in Figure 1.

As demonstrated in Figure 1, both Extended and Standard Diploma students indicated a large amount of time associated with the part time job with an average time of 8.5 hours on the weekday and 7.16 hours on the weekend for the Standard Diploma and 6.3 hours on the weekday and 6.6 hours on the weekend for Extended Diploma.

Students from online Associate Degree in Engineering (Figure 1c) spend 35 – 40 hours a week for the full time job. They attend online sessions during the weekdays and spend the most time for the self-study during the weekends.

Many students indicated having care responsibilities, such as looking after siblings and parents/grandparents. The average time associated with care responsibilities are shown to be more on the weekdays which is usually related to the family responsibilities students have to share with their parents.

Also, students indicted a large amount of time they spend for traveling to and from their home campus that often has a significant influence on their attendance of the face-to-face classes.

The above results raise an important message that non-traditional students, such as students from the low SES backgrounds, can be less successful in the HE not just because of the previous academic achievements, but also because of the significant time they are required to allocate to the non-study commitments. These students often don't have a sufficient level of support from the family (David, 2010, Brooks, 2004; Murphy, 2009), and often need to support themselves and their family working part time or looking after young brothers and sisters. That creates an extra challenge for teachers to maintain student's attendance and to keep their study motivation.

To enhance student's academic performance and motivation the development of multi-mode learning where students can obtain an extra help from co-curricular resources with the possibility to socialise with peers could be the option. With new technologies, it has now become possible for educators to self-create high-quality online resources (Bae & Lee, 2015) which can be further integrated to the course and serve as a self-study, revision tool or an alternative option for students.

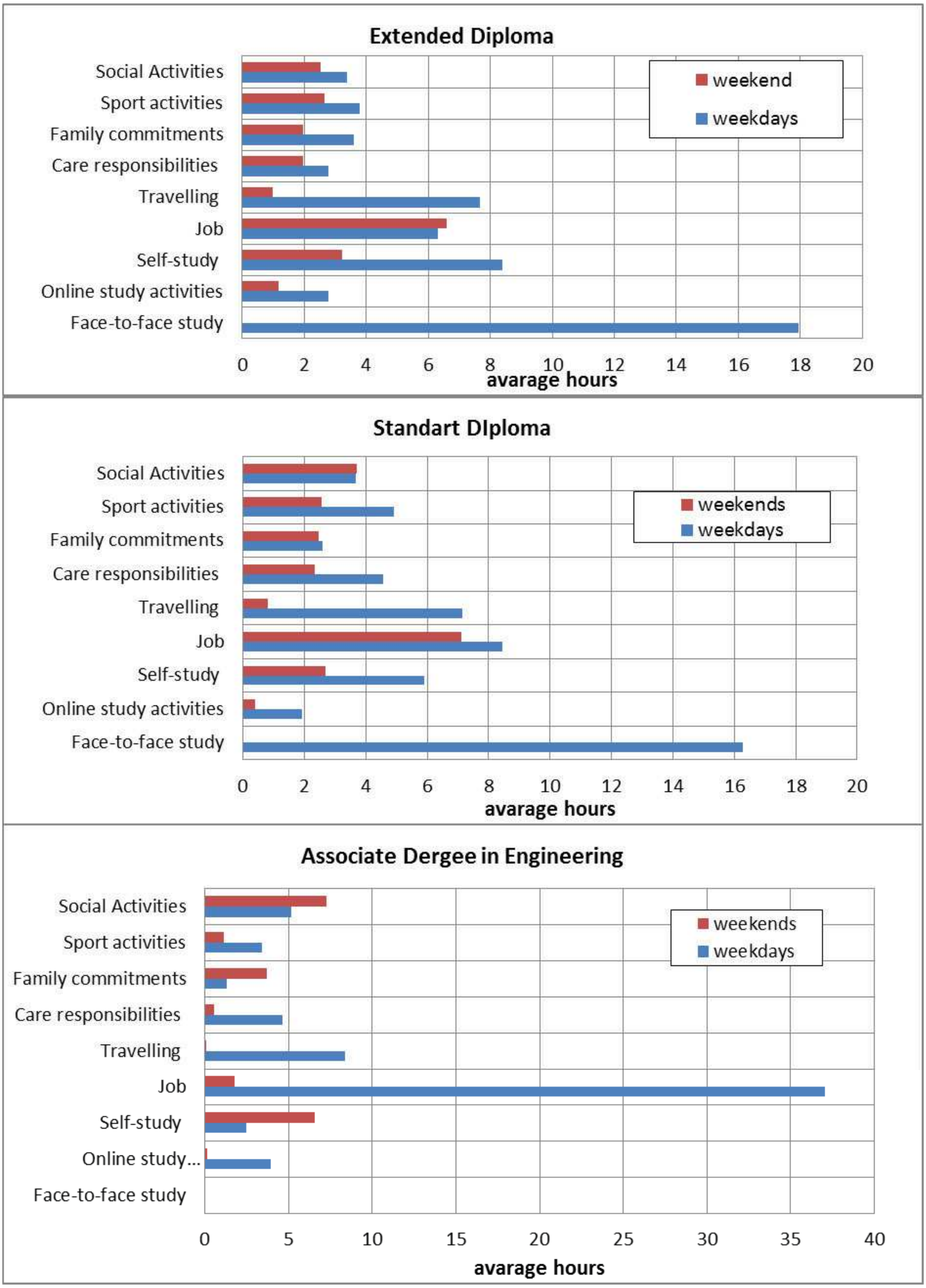

Figure 1. The summary of (A) Standard Diploma, (B) Extended Diploma and (C) Associate Degree student's commitments during the week.

Development and integration of the YouTube Channel to the first year engineering courses

According to usage statistics, all adults aged 16+ have a profile on at least one social networking site. But we can also predict that within university range this percentage is even much higher. YouTube become one of the most popular sources for students to search for video lessons and tutorials. But the large number of videos and the general low ability of first year students to search, locate, process, evaluate and use information leads to information overload, inability to find the needed information and to extract the important points. Also, it has been demonstrated that only a minority of YouTube videos related to the particular topic are useful for teaching due to misleading content and poor quality.

To increase WSU, the College student's engagement and learning performance in engineering academic pathway program a YouTube Chanel named Engineering by Steps was created.

Link to YouTube Channel:

https://www.youtube.com/channel/UCMBAl3O8EDKdXwpUDU3mMBw

The series of video tutorials in Electrical Fundamentals that are similar to the classroom working environment were created using a hand writing tool and an instructor voice over. All videos were made available to the public with enabling comments.

The videos received very positive feedback from students which also was combined with the improved unit assessment results.

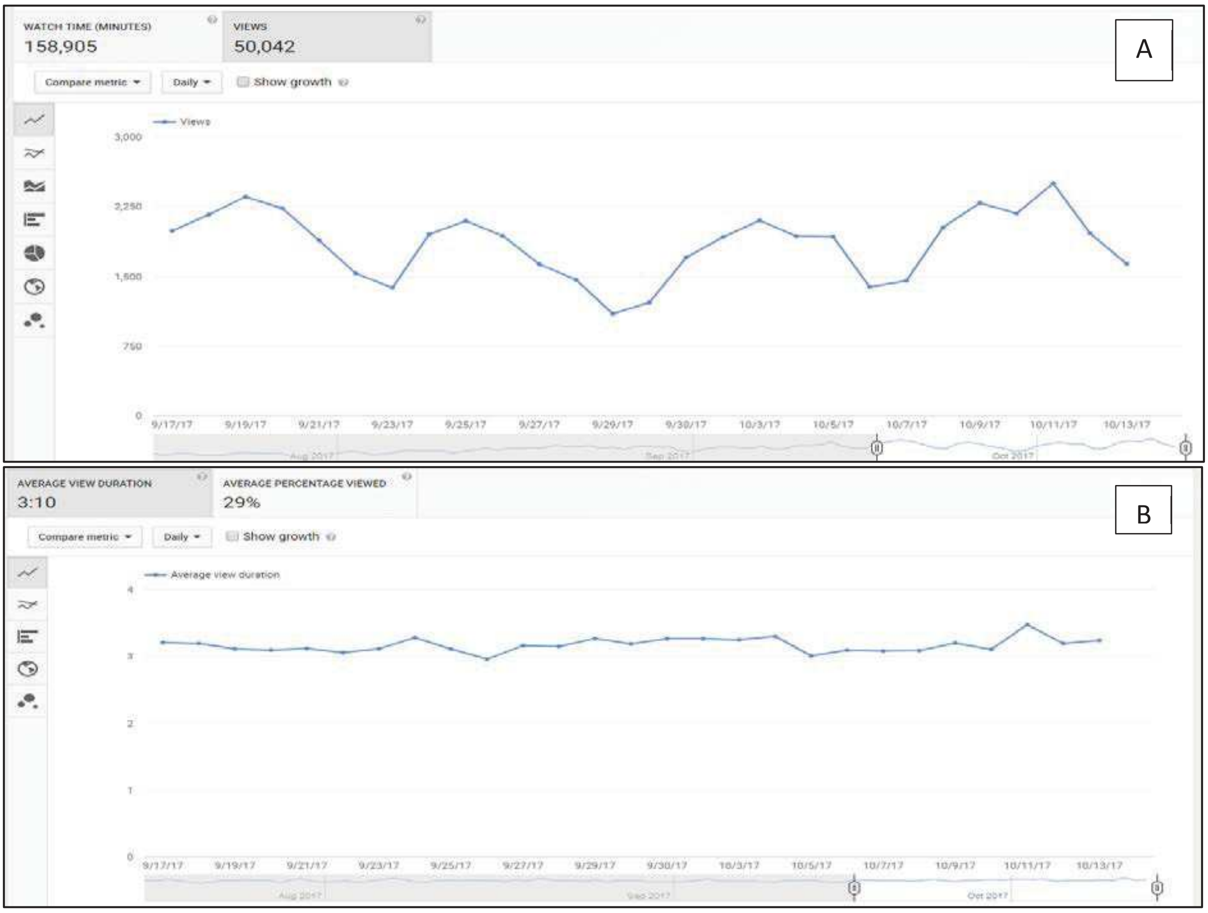

Figure 2. (A) Audience number of views and (B) retention (average minutes) reports

The YouTube statistics report (Figure 2) demonstrates stable audience interest with an average of 2000 views per day (Figure 2a) and good audience retention (Figure 2b) with an average of 3 minutes watching time per video, considering that an average length of the videos is 5 minutes. The YouTube channel wasn't specifically advertised, however for the period of three years the videos attracted over one million views, over 4,500 people subscribed, over 600 comments were posted and the videos were shared 3,500 times showing the strong interest with the wider engineering community.

When video tutorials were introduced for the first time in 2014, student's average learning experiences in the Electrical Fundamentals, collected from the student's surveys on the unit (Figure 3) showed a significant increase in the unit's 2014 score when compared to those from 2012 and 2013.

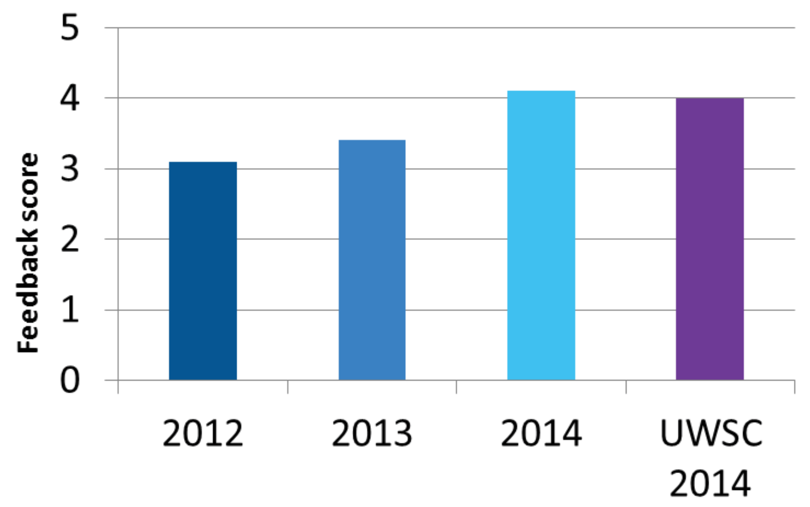

Figure 3. Feedback on student's learning experience for the Electrical Fundaments unit from 2012 to 2014 (blue) compared to WSU, the College's average feedback on all units offered campus-wide in 2014 (purple).

Student's comments from the questionnaires and surveys, as well as public comments from the YouTube channel, indicated that Social Media project had been well received. Some examples of comments include the following:

> '*Thank you so much, it helps a lot, I wish if you can solve many problems'*
>
> *'Video tutorial was useful in my study, especially when I was studying for a test at home. It did help me understand topics and it would be better if I could have video tutorials in all my subjects, especially physics and maths'*
>
> *'The videos helped me to understand the topic and basically I passed the midsemester exam be referring to the video tutorials'*
>
> *'I used videos as a guide to do extra questions and revisions'*

Conclusion

As demonstrated in this study, the journey for non-traditional students in the university pathway program isn't always easy and overwhelmed with a large number of personal commitments that are not directly associated with the study. However even being in the group of considerable financial disadvantage and low socio-economic status, the students can be motivated, talented and willing to succeed in the course which evidenced by their successful progression towards a university degree.

The development of video tutorials based on the student's needs to improve their understanding of the unit's content, helped them to learn and revise materials in their own time and to engage them in the study. From the analysis of students' feedback, YouTube data and final student's grades it can be concluded that the integration of Social Media component into the first year engineering curriculum was effective in improving the learning process, especially on issues related to an understanding of the concepts studied in class. Throughout this study, the positive global perception and satisfaction of the participants after the implementation of the videos is noticed.

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Lessons learned from the design and delivery of a new major in Humanitarian Engineering

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SESSION: S3: Integrating Humanitarianism in Engineering Education

CONTEXT
Many engineering students are socially conscious and motivated to use their engineering degrees to help tackle global problems, including those caused by poverty and natural disasters. There is a gap in the standard teaching curriculum for these students and therefore we developed a major in Humanitarian Engineering to provide initial knowledge and skills in the sector. Graduates with a Humanitarian Engineering skill set are needed in the private, public and not-for-profit sectors to apply methods of their respective engineering disciplines to meet the needs of communities globally in a sustainable and appropriate manner.

PURPOSE
In collaboration with industry, we designed and delivered a Humanitarian Engineering Major to undergraduate engineers to test the scope, achieve desirable learning outcomes and assessed student demand for this new type of education.

APPROACH
The term Humanitarian Engineering is not well defined from an educational perspective, hence the scope of the Major had to be discussed in the first instance. An industry advisory panel and a network of universities was formed to gain input on the learning outcomes and desirable graduate attributes. The Major was designed around four subjects totalling 24 units of credit, for third and fourth year undergraduates from all engineering streams. The first unit of study taught an initial understanding of humanitarian engineering, utilising lecturers and guest seminars. This subject was a prerequisite to the second subject focused on engineering for sustainability. Importantly, the third subject was a two-week fieldwork subject, where students undertook a program of activities in either a developing country or an Indigenous community. To widen the breadth of students' knowledge, a fourth subject offered choices in global health, disaster management, international project management and understanding of Southeast Asia. The fieldwork subjects were delivered first, commencing in summer of 2016. The first classroom lecture-based course was taught in the second semester of 2017.

RESULTS
The scope of Humanitarian Engineering was taken to include engineering in developing countries for development purposes, during all stages of disasters, in remote communities and Indigenous communities. Despite the low proportion of women among engineering students, there is an equal representation of gender in the program. Unit of study evaluations have returned with higher than faculty average scores and comments from several students suggested that 'this is the career path they want to take'. More detailed unit of study surveys will be undertaken to determine if the content of all the four subjects is achieving the desired learning outcomes. Further, the input of the industry advisory panel and other universities will help shape the definition of Humanitarian Engineering education. There are some informed assumptions about the contexts in which humanitarian engineers work and in-time this might prove too narrow.

CONCLUSIONS
Based on consultation with industry partners and initial experience, we suggest that subjects in Humanitarian Engineering can fill a gap in the current engineering curriculum and attract a new type of engineering student. However, more work is needed to agree on the scope of Humanitarian Engineering in the Australian higher education context. The co-ordination with industry and other universities will be critical to consolidating the educational outcomes.

KEYWORDS: humanitarian engineering, global engineering, new curriculum, sustainability

Introduction

Engineers are needed to direct meet the targets of a number of Sustainable Development Goals (SDG) (United Nations 2015):

- Goal 3: Good health and well-being needs Biomedical Engineers
- Goal 6: Clean water and sanitation needs Civil and Chemical Engineers
- Goal 7: Affordable and clean energy needs Electrical Engineers
- Goal 9; Industry, innovation and infrastructure needs Civil and Mechanical Engineers
- Goal 11: Sustainable cities and communities needs all types of engineers
- Goal 12: Responsible consumption and production needs Material Engineers
- Goal 13: Climate action needs Environmental Engineers

A new generation of engineers need to be trained to build a more sustainable and equitable planet (Amedei *et al.* 2010). There is a growing number of socially conscious engineering students who want to use their engineering degree to improve the world, both at home and abroad. However, the typical engineering curriculum does little to support an engineer to have a humanitarian-focused career (Passino 2009). The perceived lack of concern in engineering for humanitarian issues might be what some highly motivated high school students, especially women, are missing and therefore choose other specializations (Nillson 2015). Engineering fields that have clearly articulated their links to enhancing human well-being, such as Biomedical Engineering at the University of Sydney, attract the highest number of female students.

The United States has a number of well-established humanitarian engineering curriculums where the engineering students learns the engineering basics but also history, politics, economics, sociology and culture (Brown *et al.* 2014). There are an increasing number of universities in Australia undertaking curriculum development in humanitarian engineering. The Humanitarian Engineering Education Network of Australasia (HEENA) was formed in 2017 to bring together these universities.

Pedagogical objectives

The Faculty of Engineering and IT at the University of Sydney has recognized that it must better cater to students concerned about the most pressing global issues to educate engineers who can improve human lives on a large scale. Therefore, a new major in Humanitarian Engineering was proposed. The main pedagogical objectives are that the new major in humanitarian engineering at the University of Sydney should educate students in:

- The specific contexts of humanitarian engineering applied to developing countries, disaster relief and remote locations
- How engineers are critically needed to meet the Sustainable Development Goals
- Specific skills needed to work as a humanitarian engineer
- Real-life cross-cultural fieldwork
- Career pathways in humanitarian engineering

Curriculum design

The capacities outlined above clearly cannot be gained only inside classrooms. The new curriculum was designed around core elements that enable students to directly learn from people living in developing countries and remote communities by interacting with them in other than tourism or volunteer work context. To maximize learning from such practical experience the curriculum contains project-based work directly connected to theoretical content provided in the classroom courses.

Motivation and context

The institutional environment was supportive. One of the main goals of the University stated in its Strategic Plan was to "expand and diversify opportunities for students to develop as global citizens". The Faculty of Engineering and IT was also aiming to attract high school students with humanitarian ideals who would not originally connect these with engineering. A young student who is about to decide her life direction may be asking herself: "Why would I would I work on male-dominated construction sites in Sydney, when there are so many more important problems in the world?" The goal was to attract such students, equip them with skills that make them highly attractive to a whole range of employers, and expand their horizons by an intensive exposure to unfamiliar resource-constrained communities overseas and in remote rural Australia.

The decision to provide this new type of education coincided with the development of a new modular structure of Majors in the Faculty, which allowed for a coherent set of common generalist units of study to be added as a Major on top of the core of the diverse curricula of the respective schools within the faculty. It was recognized as an important goal of the major to bring students from diverse disciplines and enable them to enrich their technical expertise by learning how to apply it in unfamiliar and resource-constrained contexts. Therefore, the goal of the Major was to add breadth and understanding of practical applications in the final years of the undergraduate curricula. The Major is not standalone—its impact is in the combination with other technical parts of engineering curriculum that all students needs to master.

Industry advisory panel

Research to inform the design of the Major commenced in 2013 with the formation of an industry advisory panel. The panel consisted of 16 people representing the private sector engineering consultancy firms, large multinational organisations, non-government organisations and higher education. The scope and purpose of humanitarian engineering education was discussed within the context of industry need. During the meeting, attendees were asked to rank stated skill sets important for a humanitarian engineer, and encouraged to add and rank additional skill sets. Some of these skill sets were related and have been compiled into groups. The rankings were normalised and added for each skill set to produce an aggregate score (Table 1). The higher the score, the greater importance is attributed to the skill set. Interestingly the skills sets that were most highly rated were linked to project management, design and communication. These skill-sets needs were the foundation on which to design the curriculum for the Major.

Table 1. Industry panel ranking of the top skills sets important for a humanitarian engineer

Skill set	Score
Behaviour/ethics/working with local culture and in teams, Communications	37
Project Management, Complex systems awareness & Safety and risk	35
Dealing with public monies/policies Stakeholder consultation & participation & Project Design	27
Sustainable outcomes/capacity building/training Sustainable development - cultural, econ, social, environ Environmental Engineering	25

Market survey

The Faculty has commissioned a market survey of Year 11 and Year 12 students at several high schools in Sydney who considered studying engineering at a university. The survey also included in-depth interviews of industry experts and focus groups of undergraduate engineering students at three universities.

The findings were that Humanitarian Engineering could provide a highly distinct new educational direction and fit well with the University's reputation for social contribution. The survey identified that such a course could draw students from medicine, humanities, and science.

However, some informants were concerned about the limited application of such specialization for future work and associated "humanitarian" only with aid and disaster-relief overseas, which they found limiting. Humanitarian Engineering was less attractive for international students than for domestic students.

The recommendations of the study was that the Major should emphasise development and capacity building, rather than disaster relief overseas and that it should include domestic components leading to broader work opportunities in Australia. The study also recommended to find new partners for this Major, instead of relying on traditional partners in the construction sector, to demonstrate the new pathways that the Major opens. In summary, Humanitarian Engineering should not be simplistically framed as "engineering for poor people who cannot help themselves".

The discussions of the focus of the Major were accompanied with intensive discussions of what it should be called. In addition to the reservations regarding the narrow associations of the term "humanitarian" with disaster relief overseas, several internal and external stakeholders found the term too "missionary", "colonial", "imperial", and "overbearing". Also, there was a concern stemming from the market survey about general employers' perceptions about students with a "humanitarian" major on their diploma.

Another survey was conducted among students within the Faculty. 411 students responded to the question: "Imagine that you are a high school student selecting your future specialization and that streams with the following names are offered by the School of Civil Engineering. Considering your interests, your future career, and everything else together, would you think of choosing any of the streams listed below? Assume that you do not know their content, so you have to guess only from their names. The options provided and the results were: (1) "Global Engineering" (31%), (2) "Development Engineering" (27%), (3) "Humanitarian Engineering" (22%), and "No such stream would attract me" (21%).

The reason why the Faculty chose "Humanitarian Engineering" over "Global Engineering", which was more popular among students, was partly because the Faculty wanted to emphasize the positive societal impact as the main focus of the Major. The term "global" might not sound appropriate for projects in Australian remote communities – one of the planned target areas of the Major. (Although, it was recognized that it is possible to work on pressing issues of global importance domestically.) Moreover, the term Humanitarian Engineering was used by Engineers without Borders (although with reservations), who were identified as an important future partner for the Major. Another reason why a name which implies a focus on the human condition as compared to more normatively neutral "global" was selected, was that the term was used already by some universities overseas.

Survey of programs at universities overseas

A survey of existing programs in other countries found that some academics in the USA tend to use the term "Humanitarian Engineering" for minors and majors aimed at application of engineering in low-income contexts. Global Engineering majors and minor tend to focus more on preparing engineers for work outside of their country of origin and unfamiliar cultures but without the connotations of "helping impoverished people".

The survey did not find entire Bachelor degrees of Humanitarian Engineering but sets of units under Humanitarian Engineering label at Penn State University (Humanitarian Engineering and Social Entrepreneurship), Colorado School of Mines (Minor in Humanitarian Engineering), The Ohio State University (Humanitarian Engineering Center – including postgraduate opportunities), Massachusetts Institute of Technology (MIT Humanitarian Response Lab), and Oregon State University (Humanitarian Engineering, Science and Technology).

Some American universities used other labels for programs with a similar focus, such as Arizona State University (Global Resolve Program), University of Colorado, Boulder (Mortesen Center for Engineering in Developing Communities), and Purdue University (Global Engineering Program).

Defining the scope

As seen above, different institutions define Humanitarian Engineering in different ways. We adopted an approach that we judged appropriate for the context of an Australian university: "*Humanitarian Engineering is the application of engineering to meet the needs of communities globally; while maintaining a focus on appropriateness and sustainability".*

Humanitarian engineers are skilled engineers from all disciplines, who apply their skills and knowledge to challenges present in:

- Developing countries
- During all stages of disaster
- Indigenous communities
- Remote communities
- Global sustainability

The lesson learned from the scope of the Major was perhaps it was too broad and overlapped with components of subjects in sustainable engineering, environmental engineering and international project management. To de-conflict these overlaps the focus for the Major was emphasised to be in developmental contexts.

Designing the curriculum

When designing the curriculum it was firstly decided that fieldwork overseas and in remote communities in Australia will be a core component of the Major. Secondly, it was decided that the Major will include a unit that will be focus on sharing of experience of guest speakers from the industry. We found that our industrial partners and supporters were willing to contribute to lectures and this was seen also as an opportunity to strengthen the links between the Major and the industry. Experienced practitioners can explain to the students how to prepare for global careers, especially for work in developing countries and most demanding contexts such as disaster recovery. The units should bring together students from diverse disciplines and by letting them collaborate over two years in Sydney and overseas the intention was to develop a cohesive community and long-lasting relationships among students interested in contributing their engineering knowledge to worthy causes.

The whole structure of the Major was designed not to exclude any engineering student from any specialization by prerequisites. The selection of students to the Major would be only in terms of achievements, fit, and motivation not their specialization. The selection takes place during enrolment of the students to the fieldwork unit of study, which is an essential element of the Major. To assure students' safety in the field, the number of students acceptable to this fieldwork unit is determined by the capacity of local partners in the fieldwork location each year. This logistic necessity justified the decision not to allow some students to enrol in to the unit and therefore prevent them from completing the Major – a useful option to have for a Major in engineering with no formal prerequisites. A unit of study with no requirement in terms of quantitative skills and very open-ended outputs might mistakenly attract students who seek an easy credit and lead to problems in the field. This element of exclusivity was expected to attract top students and attract the attention of employers.

Specifically, the Major consists of four full subjects (6 units of credit each) chose from component A, B, C and D (Table 2). Then two full subjects in applied research from component E. Importantly the fieldwork component (C) was included as a critical skill-set development unit based in real-world experiences. This fieldwork was supported by Australian Government Funding through the New Colombo Plan Scheme.

Table 2. Structure of the Humanitarian Engineering Major for 36 units of credit.

	Subjects	Details
A	CIVL3310 Humanitarian Engineering	3^{rd} year elective, introduction
B	CIVL5330 Engineering for sustainable development	4^{th} year elective, greater depth
C	CIVL5330 Global Engineering Fieldwork, or SLIC 3000 or SLIC 4000 Service Learning Indigenous Communities	Two-week domestic or international fieldwork (winter and summer break).
D	ASNS2665 Understanding Southeast Asia, or PMGT3857 International Project Management EDUF3026 Global Poverty and Education ITLS6007 Disaster Relief Operations HSBH3009 International Health	Breadth subjects delivered outside of the school and can be taken at anytime
E	CIVL4022 Thesis A CIVL4023 Thesis B	Final year thesis related

Content of CIVL3310 Humanitarian Engineering

This course explores the role of engineers in disaster recovery and humanitarian assistance in the most vulnerable communities. The unit of study is concerned with ways in which engineers can help such communities deal with sudden natural or man-made shocks, before or after they occur. The students develop an understanding of the linkages between life-supporting infrastructures, well-being of community and their vulnerability to disasters. Through a set of case studies and lectures provided by guest speakers with experience of humanitarian work and international development projects, the unit raises and explores a number of questions. How can the effectiveness of "humanitarian interventions" be measured, and what are the most important determinants of effectiveness? Who makes decisions on such interventions and are they a human right? What is the role of diverse stakeholders in response to crises in vulnerable settings? How to communicate with them and cooperate with them while upholding high ethical standards and at the same time respecting their culture and the ways things are done locally? How to work with and for non-governmental and non-profit organizations? How to coordinate large international programs to respond to humanitarian crises? How to combine technological and social approaches when addressing vulnerabilities in socio-technical systems? Importantly, what role engineers currently play and should ideally play in implementing humanitarian interventions?

Content of CIVL5330 Global Engineering Fieldwork

Global engineering field work is a project-based interdisciplinary intensive unit of study in which students will explore how to utilize the knowledge gained in classroom courses to implement engineering projects in low-capacity contexts. The students gain practical experience working in teams in a safe and supervised environment by participating in real engineering projects that aim to improve living conditions of inhabitants of vulnerable communities in Australia and overseas. The projects stimulate the students' awareness of global social problems and the passion to tackle them. The students practice to communicate, develop trust, and negotiate with the local stakeholders and cooperate with the local governmental units, the private sector, and the civil society to explore the root causes of the uncovered problems. To successfully communicate their ideas, the students may need to use other languages than English. They search for potential engineering approaches to the reinvigoration of local communities and aim to achieve the best outcomes with limited public or private investments. They learn in practice that a solution to complex global social problems cannot be found through any engineering discipline alone but rather through cooperation and consultation with experts from other fields, the directly affected stakeholders, and the general public.

Content of CIVL5330 Engineering for sustainable development

The question of this course is how to build resilient cities and communities that will enable in the future inclusive social and economic growth within the planetary resource boundaries? This course is about engineering for long-term improvement of the human condition. This unit will introduce the concept of sustainable development and the role of engineering in tackling global problems. It explores the challenges encountered in running engineering projects and programs that are socially inclusive, environmentally sustainable, while contributing to economic development. The questions tackled in the unit include the following: What is development and how to measure it? What are the causes of poverty? How to build sustainable cities and rural communities that provide physical and food security to their inhabitants and enable them healthy lives? How to achieve equitable access to water and health services globally? How can improved means of public transport and information-communication technologies contribute to the social inclusion in urban and rural communities? How can engineering infrastructure and new technologies contribute to poverty reduction and sustainable growth locally and globally?

Learning outcomes

The learning outcomes were based on the skill-sets identified by the industry advisory panel

- Apply specialised engineering knowledge to propose improvements in the delivery of humanitarian and developmental projects.
- Ability to identify human issues and local constraints and design appropriate solutions.
- Ability to analyse the process of implementing an engineering solution and the ability to create better project outcomes by improving process.
- Experience in the use of assessment tools and techniques to guage community needs and/or the long-term effectiveness of develoment and response programs.
- Challenges faced by conflicting customs and competing outcomes will present dilemmas which are resolved by reference to personal accountability hierarchies.

Reference texts

A survey of reference texts was undertaken by reviewing any titles with the reference to humanitarian engineering or sustainable engineering. The results were mixed with some sustainability texts being too general in nature while some humanitarian texts focused entirely on humanitarian disaster response. After review a reference texts from Ohio State University, USA (Passino 2016), an African political economist (Moyo 2009) and The Sphere Project Handbook (The Sphere Project 2011) were selected.

Curriculum delivery

Fieldwork delivery

We needed to find a systematic, safe, and affordable way to bring a large number of students to the projects in remote communities and overseas, enable them to collaborate with local stakeholders, and at the same time deliver academic content considered worthy of final years of Bachelor of Engineering at a research-intensive university.

Partnering with Engineers without Borders and their experienced facilitators enabled to bring a large number of students to the field without prohibitive time demands on logistics management by the academic supervisors. The flip side of partnering with a 3rd party provider that runs standardised centralized programs is a partial loss of control over the management of the program and the necessity to make some compromises in terms of academic content. More customizations of the program means higher cost that need to born by someone.

The cost for our domestic students was offset by the availability of New Colombo Plan funding provided by the Department of Foreign Affairs and Trade provided by the Australian Government. The unavailability of this funding for international students raised issues of equity and eventually the School of Civil Engineering at the University of Sydney agreed to subsidise the participation cost of a limited number of highly-qualified international students each year. The question of financial sustainability will arise when New Colombo Plan funding cedes. Fieldwork will always be more costly then classroom units and subsidies provided by the University will be necessary to deliver the desired outcomes at the desired scale required by the University Strategic Plan.

In addition to the logistics in the field that is facilitated by a third party, as compared to a classroom unit of study, field work unit of study requires more administrative support before the departure. The School appointed an administrative staff member on two days per week basis to coordinate the students. Institutions that want to run similar programs should allocate necessary resources for such support. Another requirement for successful fieldwork is high academic staff to student ratio. We realized that it is optimal to have approximately one tutor per 15 students in addition to academic oversight and resources need to be allocated to this as well.

The results were good and the fieldwork proved popular among students. The applications for fieldwork for were greater than the number of places available. The actual enrolment numbers are in Table 3.

Delivery of classroom units

The first lecture subject was delivered in Semester 2 2017 with 36 enrolled students. Based on the number undergraduates and thoses that have available electives to chose majors it is estimated that the major will reach 70 – 90 students per year cohort.

Table 3. Delivery of humanitarian engineering curriculum

Unit	Delivered	Student enrolments
CIVL5330 Global Engineering Fieldwork	Summer session December 2016 – India	19
CIVL5330 Global Engineering Fieldwork	Winter session July 2017 – India	34
CIVL3310 Humanitarian Engineering	Semester 2 2017	36

Student motivation

For the lecture based subject students were asked why they had chosen the subject. Each student replied with three words. Out of the 80 responses the most frequently mentioned reason was ‘interest’ (nine counts) followed by ‘impact’ (six counts) (Figure 1). Other frequently mentioned reasons were ‘different’, ‘altruism’, ‘career’ and ‘global’ (four counts each). The wordcloud aligns with the assessment that socially aware students who want to make an impact with their degree were chosing the humanitarian engineering subject. There was reports second hand from some students that other students who were interested in the subject but had not chosen the unit because they were worried that there would be a large number of essays to write and they were concerned about their writing skills.

Figure 1. Word cloud generated from student responses to the question ‘Why did you choose to study humanitarian engineering?’

Fieldwork learning outcomes

Fieldwork subjects delivered in India and Samoa were each a two-week program supported by Engineers without Borders and based on their Design Summit program. The program has three stages of 4 days each: cultural orientation and human centred design workshops, homestay and then design and then final presentations.

For this subject additional content was introduced to students through a pre-departure workshop and assessment. The assessment consisted of: pre-departure assignment focused on the SDGs, in-country participation mark, group presentation and report video and an individual report and personal reflection.

Students were free to identify design challenges and come up with design ideas that included: water and wastewater, construction and response disater risk reduction and agricultural post processing.

Figure 2. Fieldwork pictures taken in India in December 2016 (L) and Samoa in July 2017 (R)

Student evaluation and feedback

The formal unit of study evaluations for summer and winter units of study scored satisfaction ratings above the school average (4.3 and 4.6 respectively, as compared to 3.9). Comments from the students were that the fieldwork had allowed them to apply their engineering skills to real-world problems. Many realised different career paths are available to humanitarian engineers. Students also reflected that the immersive overseas fieldwork experience improved their ability to work in teams and in cross-cultural settings. The students' experience of the domestic fieldwork was similarly positive. One student wrote that participating in the project was the most useful and important thing she has done in her life.

The Major seems to positively impact student recruitment already. The Faculty offers Leadership Scholarships to the brightest high school students. In the last round of applications, approximately 10% of applicants specifically stated that they are applying to the Faculty because of the Major and a number of other students mentioned their general humanitarian interests.

Remaining challenges

One challenge of such interdisciplinary initiative is working across administrative boundaries within the institution. Every engineering School within the Faculty needs to respect their strict accreditation requirements and ensure that each unit of study complies with competency levels defined in each School. It is challenging both in terms of time and conditions for learning outcomes to fit into these diverse and highly-demanding curricula units of study that cut across Schools.

Next, we need to ensure that once we start welcoming students who entered the Faculty only because of Humanitarian Engineering that they do not lose their motivation before they get the opportunity to immerse themselves in real projects. Embedding in the early years of the curriculum more of content that is attractive to such students will be necessary.

Finally, in addition to the collective fieldwork units, a remaining challenge is to develop sufficient opportunities and resources for Humanitarian Engineering students' final projects and theses.

Conclusions

Engineering should be about making lives better. We need to expand our degree programs to provide our students who want to improve the world with an understanding of the needs of people who are without adequate access to energy, shelter, water, and sanitation. The Humanitarian Engineering major is a response to the global need to educate engineers to meet the SDGs. We hope that as word spreads about the Major that more like-minded students will enrol. Evidence from the most recent high school students' scholarship applications suggest so. The purpose of this paper was to share within HEENA network and beyond our experience in developing the major and the challenges encountered in different stages of the process. We hope this will contribute to further development of Humanitarian Engineering education in Australia and overseas.

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Towards a framework for evaluating diversity in STEM outreach programs

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CONTEXT

In recent years, the Science, Technology, Engineering, and Mathematics (STEM) professions have been making significant efforts to attract and retain a broader cross-section of the community to study engineering, and in turn enter the engineering profession. This is often done through outreach programs with primary- and high-school students. However, there is no recognised framework for providers of these outreach programs to evaluate whether their activities are leading to the broadening of undergraduate intake or diversity in the profession.

PURPOSE

This study will consider existing professional inclusion and diversity frameworks and their potential application to STEM outreach activities. This will provide insight into and a potential platform to evaluate diversity initiatives in STEM outreach activities.

APPROACH

Diversity and inclusion frameworks created by business, government, and university bodies are analysed for common themes. These themes are considered alongside the literature around the attraction of students of diverse backgrounds into STEM to identify areas where STEM outreach may be able to learn from work done by professional bodies.

RESULTS

This review brings together the literature on early pathways to STEM and the best practice of professional bodies in regards to retaining people with diverse backgrounds. Areas that require further investigation for the creation of a full evaluation framework are highlighted.

CONCLUSIONS

It is currently challenging to objectively assess the value of STEM outreach activities. This review will provide a specific platform for a framework to evaluate STEM outreach activities, with a focus of attracting more students with diverse backgrounds cohorts into STEM professions.

KEYWORDS

STEM education, outreach programs, diversity, inclusion, framework

Towards a framework for evaluating diversity in STEM outreach programs

Introduction

The growth of the science, technology, engineering, and maths (STEM) workforce has been described as “critical” for Australia’s economy and prosperity (Office of the Chief Scientist, 2016). However, Australia is currently training fewer STEM professionals than it needs to stay competitive on the international stage (The Australian Industry Group, 2015). STEM-based educational outreach (EO) activities have been a long-term strategy to build awareness of tertiary study of STEM subjects, as an important step towards a STEM career.

There has also been popular recognition of the need to attract talent from diverse backgrounds into STEM careers. As a place of early exposure to opportunities in STEM, EO providers connect with children and young adults, who are already forming stereotypes about STEM careers (Frost & Diamond, 1979; Levy, Sadovsky, & Troseth, 2000). At this early decision point (Correll, 2001; X. Wang, 2013), EO activities play a key role in providing positive impressions of STEM fields to people from diverse backgrounds and currently underrepresented groups.

However, there is no recognised framework for EO providers to inform and evaluate their organisational strategy with respect to attracting people from diverse backgrounds into their programs and into further STEM-related studies. This paper investigates current benchmarking and diversity frameworks in governments, business, and universities and from this, highlights relevant factors for measuring diversity and inclusion in STEM EO activities.

Defining Diversity Groups

There are many definitions of diversity and underrepresented groups, each geared towards describing diversity in different contexts. For this review, diversity groups identified by the Diversity Council Australia (Diversity Council Australia, 2017), the Australian Commonwealth Government (Department of Employment Education and Training, 1990), and the UK’s Science Council and Royal Academy of Engineers joint Diversity Progression Framework (Royal Academy of Engineering, 2015) were considered. These were chosen to ensure the underrepresented groups were relevant to Australia, the higher education context, and STEM fields. The Diversity Progression Framework was chosen despite its UK context, as it was difficult to find an Australian counterpart who provided a similar holistic definition.

From these sources, five diversity groups were identified, and will be considered further in this review:

- Aboriginal and Torres Strait Islander peoples (Indigenous)
- Women in STEM
- People with disabilities
- People who identify as LGBTQ+
- People from minority race and ethnicity groups

Situating STEM Educational Outreach Programs

STEM EO includes activities which promote learning and engagement with STEM subjects, but operate outside of regular curricula and are typically run by an external partner or provider. STEM EO can be pitched anywhere on a spectrum of student interest and experience – from students who have had limited opportunities or interest and are experiencing STEM for the first time, to students who have shown an aptitude in STEM and are being extended in a specialist area. As such, EO is one way that students from diverse backgrounds who are not formally engaging with STEM subjects may interact with professionals in STEM fields or STEM subject-matter. It is important, then, that these programs are attractive to students with diverse backgrounds and encourage further engagement.

The choice to adopt a STEM pathway can be viewed in relation to Rogers (2003) Innovation-Decision Process, where there are five stages of adoption: knowledge, persuasion, decision, implementation, and confirmation. These stages are explained and applied to the STEM EO context in Figure 1 below.

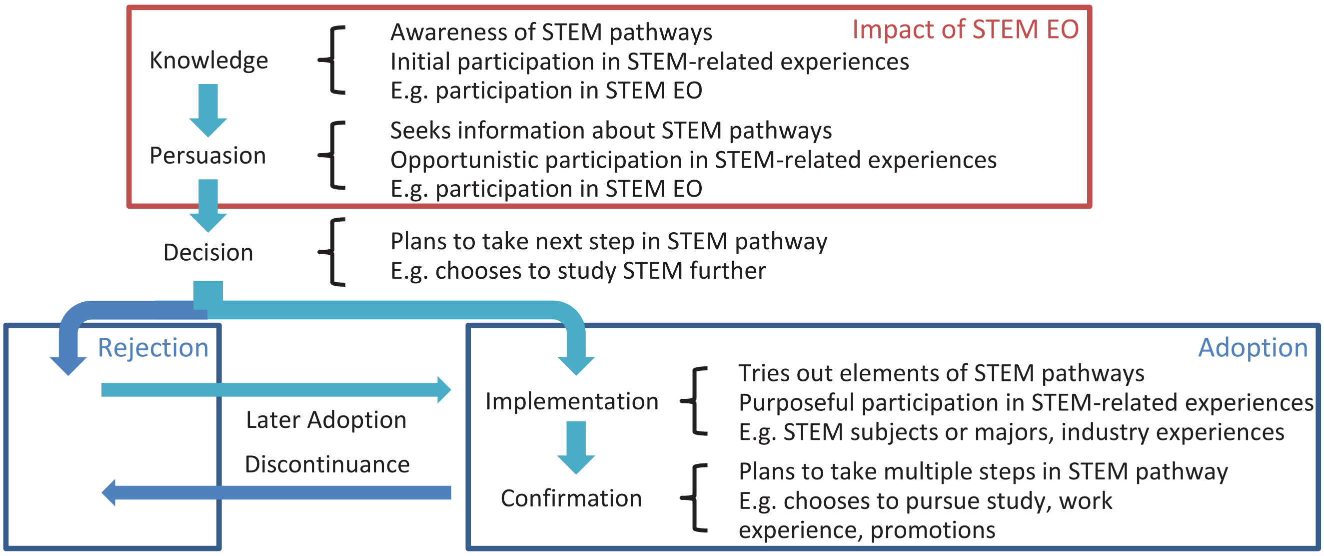

Figure 1: Innovation-Decision Process, Adapted to STEM Pathway

As an opportunity for exposure or extension, STEM EO offers a chance for students to engage with the initial two stages, knowledge and persuasion. This is particularly important for those students who are not gaining this experience through traditional pathways such as school.

Factors for attracting students to a STEM pathway

If STEM EO programs are to effectively provide students of diverse backgrounds exposure to and initial experiences in STEM pathways, they must be effective in both attracting and retaining students of all backgrounds to STEM. Key influences on a student's aspirations to a career in STEM include (Andersen & Ward, 2013; Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; Dick & Rallis, 2017; M. Wang & Degol, 2013; X. Wang, 2013):

- achievement in STEM-related subjects
- self-efficacy in STEM subjects
- perceived relative advantage in a STEM career, such as perceptions of pay opportunities, job security, or opportunity to be challenged
- the influence of others, such as parents, teachers, peers, and STEM professionals

However, these influences are not uniform across all underrepresented groups, and each influence will be discussed briefly below.

Achievement in STEM-related subjects at high school level is a positive influence on a student's choice to choose a STEM career. Andersen & Ward's (2013) analysis of data from the High School Longitudinal Study of 2009 found that while the effect of science attainment was consistent across ethnic groups studied (Black, Hispanic, and White), Black students were more likely to consider mathematical attainment of importance. Ability in other areas affects career choice – mathematically capable students with high verbal skills are less likely to pursue STEM careers than those with high mathematical skills but moderate verbal skills

(M. Wang, Eccles, & Kenny, 2013). This has been linked to a higher number of women leaving STEM majors (Wai, Lubinski, & Benbow, 2005).

Self-efficacy refers to a student's belief about their own ability. Self-efficacy can predict career choice better than personality matching, thinking consequentially about potential difficulties, or outcome expectations (Bandura et al., 2001). However, the effect of stereotype threat often negatively affects self-efficacy; for example, causing women to perform more poorly in STEM subjects (Cadinu, Maass, Rosabianca, & Kiesner, 2005) and meaning women tend to feel more need than males to be prepared for the mathematical aspect of engineering before they will consider it as a feasible career option (Frehill, 1997).

Perceived relative advantage in a STEM career can include a student's assumptions or stereotypes about the job, their perception of pay, security, and prestige, and other future benefits of studying STEM. The "Draw a Scientist" test has uncovered that students across ages, gender and ethnic groups have a perception of scientists as Caucasian and male, working with technology in a laboratory (Finson, 2002). Cheryan et al. (2011) suggests that aspects of these stereotypes may keep students, particularly those who do not fit the stereotype, away from STEM. Andersen & Ward (2013) found that Hispanic students considered STEM utility—the perception that a STEM subject or major will benefit the student in the future—to be more important than students of other ethnicities.

As with the previous factors, the influence of others in a decision to pursue STEM careers varies across demographic groups. For example, women are more likely to draw their self-efficacy from social persuasions such as encouragement from family members, teachers, and peers, while men's self-efficacy is more likely to be influenced by their interpretations of their achievements (Zeldin, Britner, & Pajares, 2008; Zeldin & Pajares, 2000).

Beyond the individual factors for attracting students to a STEM pathway, students of diverse backgrounds also face additional challenges after entering a STEM environment. Cutts-Worthington (2017) explores key factors impacting representation in engineering for underrepresented gender and ethnicity groups, Indigenous students, students from low socio-economic backgrounds, students with disability, and LGBTQ+ students in an Australian context. Cutts-Worthington identified five key factors impacting retention of students of diverse backgrounds: sense of belonging, academic preparation, perception of engineering, stereotype threat, and financial burden. Other, less-significant factors of note were representation, career concerns, and discrimination and bias.

It is important to note that areas of diversity cannot be simply considered separately. Students at the intersection of two or more areas of diversity may be influenced in a way that is not a direct addition of the research concerning the two areas separately. It is also important to note that there is a range of diversity within each area of diversity, as identified in this paper. For example, students with physical disabilities may experience these factors in a very different way to those with learning disabilities or mental illness. Lastly, the research so far focuses much more on differences across gender and ethnicity than it does on LGBTQ+, Australian Indigenous, and people with disability.

Existing frameworks for diversity

For each of the five diversity categories selected for this review two peak bodies were chosen that:

- demonstrate representation of that diversity category
- have a defined framework, benchmark or award program
- demonstrate influence or impact in one or more sectors

Impact was measured on an adapted Impact Management Planning and Evaluation Ladder (IMPEL) (Department of Education and Training 2016). Only frameworks from organisations demonstrating Level 5 impact—narrow opportunistic adoption were considered. Preference was also given to frameworks pertinent to STEM or educational contexts, or aimed at an

Australian audience. These were then analysed to provide insight into the potential usefulness of these frameworks in a STEM EO context.

Table 1 outlines the 10 frameworks chosen for the review. The organisation's purpose or vision is listed alongside their membership or reach as an indication of their influence.

Table 1: Organisations providing Frameworks

Equity Group	Organisation	Purpose	Membership/Reach
Indig-enous	Universities Australia [a]	Represents Australian universities	Universities in Australia
	Council of Australian Governments (COAG) [b]	Coordinates strategic policy on education	Educators in Australia
Women in STEM	Workplace Gender Equality Agency (WGEA) [c]	Promotes gender equality in workplaces	Workplaces in Australia
	Science in Australian Gender Equity (SAGE) [d]	Supports gender equity in STEM and medicine	Australian universities and workplaces
Disabilities	Australian Local Government Association (ALGA) [e]	Serves as national voice for local councils	Local government across Australia
	Australian Network on Disability (AND) [f]	Advances the inclusion of people with disability in business	Workplaces in Australia
LGBTQ+	Pride in Diversity (PiD) [g]	Reducing exclusion, and homophobia in the workplace	Workplaces in Australia
	Beyond Blue [h]	Provides information and support for mental health	Health services, schools, workplaces
Minority ethnicity	Equality Challenge Unit (ECU) [i]	Support ethnic diversity in higher education institutions	Universities in the UK
	Business in the Community [j]	Building a fairer society and more sustainable future	Businesses in the UK

[a] (Universities Australia, 2013) ; [b] (Education Council, 2014); [c] (Workplace Gender Equality Agency, 2017); [d] (Science in Australia Gender Equity, 2017); [e] (Australian Local Government Association, 2010); [f] (Australian Network on Disability, 2017); [g] (Pride in Diversity, 2015); [h] (Beyondblue, 2016); [i] (Equality Challenge Unit, 2017); [j] (Business in the Community, 2017)

Major themes, or attributes, found across the frameworks were identified through a thematic analysis. The frameworks were then mapped against these themes to give an understanding of the importance and prevalence of these attributes.

Common attributes across frameworks

Twelve common themes, or attributes, derived from the frameworks listed in Table 1 are listed and described in Table 2 below.

Table 2: Attributes derived from Frameworks

	Attribute	Framework principles coded to this attribute discussed…
Standard Operating Activities	Policy/ Accountability	• Development of procedure, policy, or strategy to make the organisation more diverse or inclusive • Transparency or accountability throughout the organisation
	Formal Structures	• Creation of positions, committees or other groups, or feedback systems to improve diversity and inclusion
	Evaluation /Review	• Collecting data or information about the current state of the organisation • Review of initiatives or actions taken towards increasing diversity and inclusion • Reporting mechanisms or processes
	Training Staff/ Students	• Training for staff or students about diversity and inclusion • Ensuring that staff or students have the skills they need to be inclusive • Development or training given to diverse staff or students
	Representation/ Recruitment	• The representation of equity groups within the organisation, sometimes at different levels within the organisation • Attracting and recruiting people from equity groups into the organisation
Organisational Attitudes	Leadership Support	• Inclusive statements or policy created or signed off by the organisation's upper leadership • Actions or embodiment of framework principles by the organisation's upper leadership
	Seeking/ Using Best Practice	• Pursuing or reading research to understand and implement new ideas pertaining to diversity and inclusion • Commitment to innovative activities or "doing better" • Concepts that take diversity and inclusion beyond compliance
	Welcoming Culture	• Encouraging, promoting, or incentivising inclusive behaviour • Creating physical environments that acknowledge or celebrate diverse groups
	Support Diverse Groups	• Initiatives designed to promote diversity and inclusion, such as ensuring resources are sensitive and accessible, adjustments being made, or policy being changed
	Acknowledgement of Intersectionality	• Understanding the interplay between equity groups, and that they cannot be considered as completely separate • Acknowledge that an individual may not belong to only one equity group
External Relationships	Community Links/ Consultation	• Seeking input or looking for feedback on diversity and inclusion actions from the local community or other organisations • Seeking input or looking for feedback on diversity and inclusion actions from people who identify with the equity group in question
	Impact Outside the Organisation	• Choosing or influencing suppliers and customers to adopt a similar value of diversity and inclusion • Considering the organisation's ability to serve customers in equity groups

Table 3 (in the appendix) maps between the attributes identified in Table 2 and the frameworks that they occurred in. The spread of attributes across the frameworks concerned with different equity groups suggest that at least some of the attributes of a good diversity and inclusion framework are shared across the different types of diversity.

Application to STEM Educational Outreach

In this paper, three areas of concern relating to diversity in STEM EO have been identified:

- the people in diversity groups
- the factors that influence a decision to explore a STEM pathway
- the organisational attributes which promote diversity

These have been summarised in Figure 2.

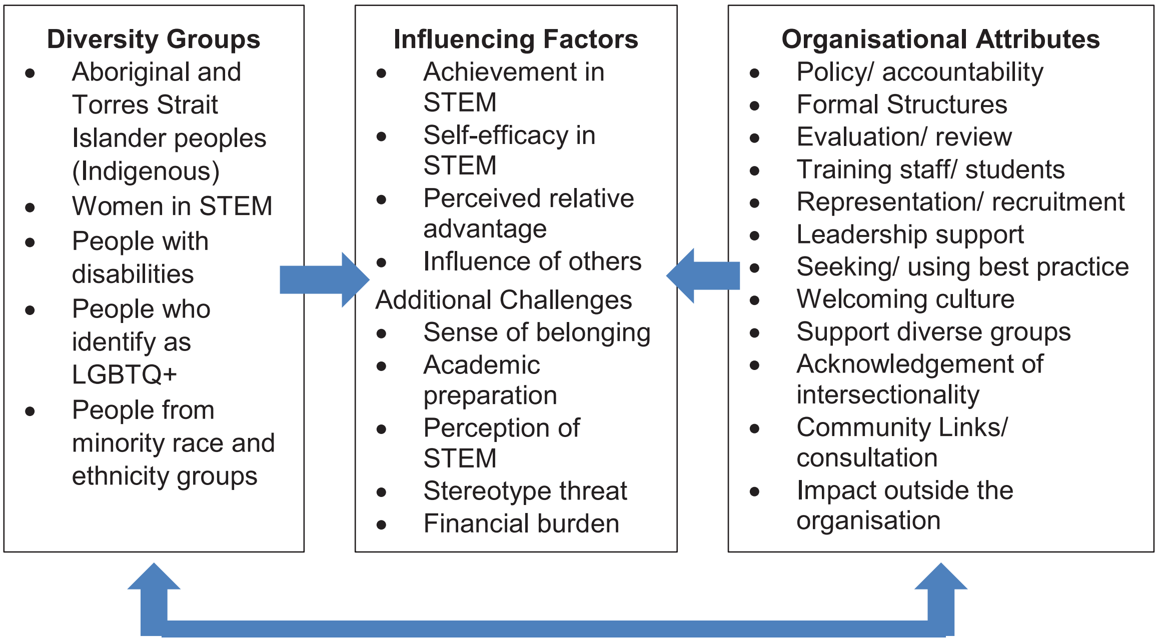

Figure 2: Summary of Diversity Groups, Factors, and Attributes

Understanding the relationships between these three areas (represented by the arrows in Figure 2) is a key area of further work for reducing the barriers for a STEM career for diverse people.

It is important to recognise the nuances in how the different diversity groups experience and perceive the factors that encourage students to explore the STEM pathway. As evidenced in this review, not all factors apply equally to all groups of students, and this becomes even more complex when considering individuals who may fit in multiple groups. Each person's individual characteristics and identities will affect how they see and react to the activities of STEM EO.

Organisational attributes describe the implicit and explicit actions both within and outside of an organisation. It is here that STEM EO organisations can make systemic change to affect diversity. However, initiatives at organisational level may affect multiple influencing factors in different ways. Understanding the relationship between organisational attributes and the factors that influence students along the STEM pathway will allow STEM EO organisations to make informed decisions about their diversity policies and strategies.

The strong commonalities between frameworks directed at different diversity groups suggest that some measures may lead to better inclusion for all groups; however, the differences between the emphases of frameworks suggest that different groups are also likely to require tailored support. Understanding how initiatives targeted at one diversity group may affect other diversity groups is also of importance.

A further consideration when looking at STEM EO organisations is the broad variety of activities that make up EO. The STEM Program Index 2016 (SPI) (The Australian Industry Group, 2016) lists a wide range of STEM EO activities, including after-school clubs and holiday programmes, competitions, excursions, in-school programmes, mentoring, school visits, out of school programmes, and residential programmes. These programs are delivered by a wide variety of organisations, including universities, museums, not-for-profits, foundations, and both small and large businesses. The recent interest in STEM also suggests there may be a number of start-up groups delivering outreach activities. These groups may have an entirely different organisational structure to the groups targeted by the frameworks used in this review. Understanding the different organisational contexts is an important factor for investigating diversity in the STEM EO sector as a whole.

Conclusions and Future Work

If the STEM field is to increase diversity at industry level, it must consider how diversity can be increased at earlier stages in the STEM pathway. It is important, then, to consider how diversity can be improved in the first impressions that STEM EO provide at the early stages of the innovation-decision process.

This review has investigated the frameworks used by businesses, government and universities to improve diversity across five underrepresented groups, and considered how these may be useful for the STEM EO context. From this, 12 common attributes were identified. In addition, nine key factors and challenges that influence students to adopt STEM pathways were identified from the available literature.

Having identified these attributes, further work in this area is required to assemble these considerations into a coherent framework which can be applied to the niche area of organisations working in STEM EO. This review and its findings form only preliminary work in understanding what must be done to measure and affect participant diversity in STEM EO organisations. Future work will require a considerable understanding of how diversity groups and organisational attributes influence the decision of individuals into a STEM pathway.

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Appendix

Table 3: Framework-Attribute Mapping

	Attributes / Organisation	Policy/ Accountability	Formal Structures	Evaluation/ Review	Training Staff/ Students	Representation/ Recruitment	Leadership Support	Seeking/ Using Best Practice	Welcoming Culture	Support Diverse Groups	Acknowledgement of Intersectionality	Community Links/ Consultation	Impact Outside the Organisation
		Standard Operating Activities					Organisational Attitudes					External Relationships	
Indigenous People	Universities Australia	■	■	■	■	■	■	■	■	■			
	COAG Education Council			■		■		■	■	■		■	
Women in STEM	WGEA	■		■	■	■			■	■			■
	SAGE	■		■	■	■	■		■	■	■		
People with disabilities	ALGA	■	■	■	■	■	■	■				■	
	AND			■		■		■		■			■
LGBTQ+	PiD	■	■	■	■		■	■	■				
	BeyondBlue	■		■			■	■	■				
Minority ethnic groups	ECU			■	■	■	■	■		■	■	■	
	BiTC		■	■	■	■		■		■			■
	Instances (/10)	6	4	10	7	8	6	8	6	7	2	3	3
	Instances across Diversity Groups (/5)	4	4	5	5	4	5	4	3	4	2	3	3

A systemic approach to improving tutor quality in a large unit

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CONTEXT

In a large unit with several hundred students it is almost impossible for a unit co-ordinator to provide the support, guidance and personal attention that all students need. In such cases the burden of care falls largely on sessional tutoring staff. Since this is a perennial problem it is therefore important that a systematic evidence based approach be used for empowering tutors to meet the needs of students. The paper will argue that the best system to use is one that adheres to the known evidence on i) how to recruit staff and ii) how to best train the recruited staff effectively, given the limited training resources available.

PURPOSE

The purpose of this paper is to investigate whether implementation of an evidence based system for recruiting and training tutors translates to improved teaching outcomes.

APPROACH

The approach was to trial the evidence based system for recruiting and training tutors in a large first year engineering unit (ENGG1300) and to evaluate the results. The recruitment strategies included a) the use of written applications, b) interviews with structured behavioural questions, c) testing applicants on a task they are likely to perform when they tutor, and d) preferencing those with demonstrated conscientiousness in their academic record and prior successes in teaching or tutoring (Schmidt and Hunter, 1998; Bock, 2015). The evidence based training strategies included microteaching (videotaping teaching and then watching it back in the presence of a mentor) and personal mentoring (Hattie, 2008). The success of the system was evaluated by i) comparing student satisfaction of tutor scores in ENGG1300 with other units, ii) exploring ENGG1300 tutor perceptions of the tutor recruitment and training system via a focus group among tutors, iii) exploring ENGG1300 student perceptions of their tutors via a focus group for students and iv) extracting unsolicited student comments on tutors in independently conducted unit evaluations.

RESULTS

The findings indicate that the interventions have been quite successful. The indicators of success include i) student satisfaction scores for tutors in ENGG1300 which are higher than in other comparable units, ii) positive findings from the focus group for students with regular comments such as “the tutors in ENGG1300 are better than the tutors in other subjects” and “they are *all* good”, iii) positive findings from the focus group for tutors indicating that tutors are very satisfied with the processes in place for tutors and iv) a particularly large number of new applicants for tutoring in ENGG1300.

CONCLUSIONS

It is concluded that strong tutor performance is achievable if evidence based practices are used in both recruitment and training.

KEYWORDS

Tutor recruitment, tutor training, evidence based practice.

Introduction

Every year at the University of Queensland about 850 students take the first year Electrical Engineering unit, ENGG1300. About 500 of these students take it in Semester 1 and about 350 take it in Semester 2. In such large units the students have much more contact with the tutors than with the lecturer and so it is very important that the tutors do a good job.

There are typically 10-14 tutors employed each semester and their main task is to facilitate activities in the active learning sessions, which run for two hours twice a week. About 3 new 'junior tutors' are employed each semester, with these tutors not having tutored previously in ENGG1300. The other tutors have worked in ENGG1300 before and these tutors are referred to as 'senior tutors'.

A typical active learning session is staffed by 4-5 tutors and involves about 80-100 students. During these sessions the tutors assist student teams to:

- solve theoretical problems,
- build circuits and
- conduct measurements to verify their theoretical solutions.

Before attending the active learning sessions the students are asked to read preparatory documents and/or watch videos. There is no summative assessment in the active learning sessions, apart from a practical exam which occurs around Week 10 of the 13 week semester. Despite the lack of summative assessment in the active learning sessions, attendance is relatively high, with student feedback suggesting that the strong attendance rates are because the sessions are helpful to learning.

This paper explores the important issue of how to facilitate high quality tutoring. A number of proactive evidence based initiatives have been pursued and tested in ENGG1300, and they will be discussed in the following sections.

Tutor recruitment

According to the work in (Hattie, 2003), about 50% of the variance in a person's achievement comes from the person themself, while 30% comes from the trainer. In training tutors, then, it is the inherent ability of the tutors themselves which is likely to be the most important predictor of good outcomes. The greatest gains in tutor performance, therefore, are likely to come by recruiting the tutoring applicants with the greatest potential.

Because of the importance of tutor recruitment, ENGG1300 has adopted an evidence based approach. Research studies suggests that the best way to find recruits for a job is to seek out people who (Schmidt and Hunter, 1998; Bock, 2015):

- can demonstrate good performance on tasks they will perform in their job,
- have the requisite level of general cognitive ability,
- are conscientious, and
- perform well in structured interviews that involve questions with proven ability to separate good future performers from weak ones.

Using a combination of all four of the above discriminators tends to work better at finding the right staff than using any single one of them alone. Accordingly, within ENGG1300 at the University of Queensland, priority is given to recruiting those who:

- have a high GPA (and presumably therefore have good general cognitive ability),
- have a consistently good (rather than sporadically good) academic record, suggesting that they are conscientious,

- can provide good answers to a set of structured interview questions (such as those provided in Appendix I), and
- have prior teaching experience with good performance or can perform well on an unrehearsed teaching task in an interview. One such task might be to explain to the unit co-ordinator how to find a Thevenin Equivalent Circuit.

Tutor training

While judicious selection of tutors is important for finding tutors with good potential, shrewd training is important for developing that potential. As such, it is important to consider the evidence on what kind of training works best. Conventional teacher education (via courses such as Dip Ed and Bachelor of Education) do not work well – these courses tend to have an effect size of only 0.11 (i.e. they tend to increase achievement in students by only about 1/9 of a standard deviation) (Hattie, 2008). This represents a very small payoff, given the resources typically poured into conventional teacher education courses.

According to the work in (Hattie, 2009; Bloom, 1984), two training interventions which have much higher effect sizes are:

- microteaching (effect size = 0.88), and
- personal tutoring/mentoring (effect size = 2.0).

The following sub-section section discusses microteaching, while the subsequent one discusses personal tutoring/mentoring.

Microteaching

Microteaching requires that a trainee:

i) prepare and perform some teaching,
ii) watch a video replay of that teaching in the presence of a supervisor,
iii) self-reflect on ways to improve their skills after watching the video,
iv) listen to feedback from the supervisor after jointly watching the video with their supervisor, and
v) act on the self-feedback and supervisor-feedback to improve future teaching.

Microteaching is implemented in ENGG1300 according to the following methodology. The junior tutors are advised of the need to do microteaching before the semester commences, and the process starts formally in about Week 5. Around that time one of the senior tutors organises an information session for the new tutors in which microteaching assignments are planned. These assignments involve the new tutors giving a brief presentation to the class and/or leading a small part of the active learning session. Advice is given on how to prepare for the session and how to get the most out of the exercise. The presentations or leadings of the session are videotaped and subsequently watched back by the new tutor, who then reflects on how to improve. The senior tutor also provides feedback to stimulate further reflection.

Each junior tutor does at least one microteaching session and preferably two in their first semester of employment. These exercises help to advance the expertise of the new tutors and equip them to transit from novice to expert comparatively rapidly.

Personal tutoring/mentoring

Personal tutoring can increase achievement by up to about 2 standard deviations. This is generally considered to be a practical upper bound on the level of improvement that is possible. However, the 2 standard deviation increase only happens if there is a relatively intense investment by the personal tutor into the learner. Lesser increases tend to occur when lesser investments are made (Bloom, 1984).

The personal tutoring/mentoring intervention used for ENGG1300 operates on two levels. Firstly, an academic is involved in tutoring/mentoring one or more of the senior tutors (as well as the new tutors to a lesser extent). Then the senior tutors engage in tutoring/mentoring of the new tutors.

<u>Personal mentoring of junior tutors by senior tutors</u>

Commencing tutors are assigned to an experienced tutor who works together with them in one or more active learning sessions. The senior tutor helps to set expectations for what will be required of the new recruit.

The new tutors begin by performing the more straightforward tutoring tasks (such as answering student questions) from the start of the semester. As the semester progresses they are gradually drawn into performing the more challenging tasks (such as leading active learning sessions and giving brief presentations to reinforce technical material). Until Week 5 of the semester the new tutors are asked to simply observe the more challenging tasks being performed by the senior tutors.

Commencing in about Week 5 the junior tutors are required to prepare a number of five minute presentations for the students, and they are encouraged to incorporate some measure of interaction within these presentations. One or more of these presentations will be implemented according to the microteaching methodology. The exact nature of the concepts to be presented is negotiated between the trainee and their mentor.

The mentor takes responsibility (along with the unit co-ordinator) for helping the trainee to develop other aspects of their teaching capabilities as well. This mentoring involves such activities as:

- providing reflections on the trainee's classroom management, pacing, and manner with students,
- offering suggestions on alternative ways of doing explanations, activities, interactions with students, etc.

As the semester continues the junior tutors are given more opportunities to practice the more complex tasks. Additionally, the new tutors have the benefit of the anonymous student feedback provided by the university's teaching evaluation at the end of the semester. When the tutors commence their second semester of employment it is assumed that they will have grown in confidence and skill sufficiently to be able to lead whole sessions by themselves.

Expectations are also set for conscientiousness in the workplace. Tutors are advised, for example, that they are not to use their phone during the tutorials.

<u>Personal mentoring of tutors by an academic</u>

To facilitate the tutoring/mentoring of the tutors, the academic staff have:

- prepared lesson plans to guide the steps of the lead tutors,
- created pre-reading videos which model the kinds of presentations, clarifications, question posing and/or question answering that are required from the tutors,
- personally worked side by side with a number of the senior tutors in the active learning sessions, and participated in exchanging feedback, providing examples, and giving instruction to the tutors on evidence based teaching principles,
- encouraged the tutors to undertake special initiatives for developing personal rapport with students. This has included the making of raps, music videos, game shows, etc. One of the out-workings of this encouragement was a rock video compiled by the tutors to instruct students on how to prepare for their prac exam

(https://www.youtube.com/watch?v=63zhUJjqjTU). This video has now had over ten-thousand views on You-Tube.

Quantitative evaluation

Independently conducted tutor evaluation scores:

The overall ENGG1300 tutor evaluation scores obtained in the independently conducted university tutor evaluations were very high, with the average score in semester 1 of 2017 being 4.77/5.0. Certainly, the students at least, believed that the tutors were doing a very good job.

Additionally, the average overall student evaluation score for ENGG1300 in 2017 was 4.5/5.0. By comparison, the average overall unit satisfaction score for first year engineering units was 3.76/5.0. Given that most of the learning for the unit tends to take place in the sessions run by tutors, the high unit evaluation score would seem to be a further student endorsement of the quality of the tutors.

Tutor recruitment:

One of the metrics used to recruit tutors was GPA. This section examines whether or not there is a correlation between GPA and tutor performance. To estimate the latter (albeit imperfectly), the average tutor ratings of students were used. Figure 1 shows a scatter plot of average tutor evaluation score vs. GPA. The correlation coefficient for the scatter is 0.1719 and thus there is quite a weak relationship between GPA and tutor evaluation scores.

In hindsight, the weak correlation is not surprising. Studies have shown that a certain 'threshold' level of general cognitive ability is necessary for a person to perform well in the workplace, but beyond that threshold level, cognitive ability tends to be relatively unimportant (Vaillant, 2012). Tutors for ENGG1300 were not recruited unless they had a moderately high GPA and so it is not surprising that GPA does not greatly impact on ENGG1300 tutor performance.

Tutors were also recruited based on prior tutoring experience, whether that be in high school tutoring, private tutoring or coaching, or tutoring at university. It is of interest to know whether prior experience in tutoring in ENGG1300 is a better predictor of tutoring in other areas. To test this notion, a correlation was performed between the tutor evaluation scores in 2017 vs. the number of semesters of prior tutoring experience in ENGG1300. The correlation coefficient was found to be 0.0167. The very low level suggests that tutoring of any form is effective for preparing people to do a good job of tutoring in ENGG1300.

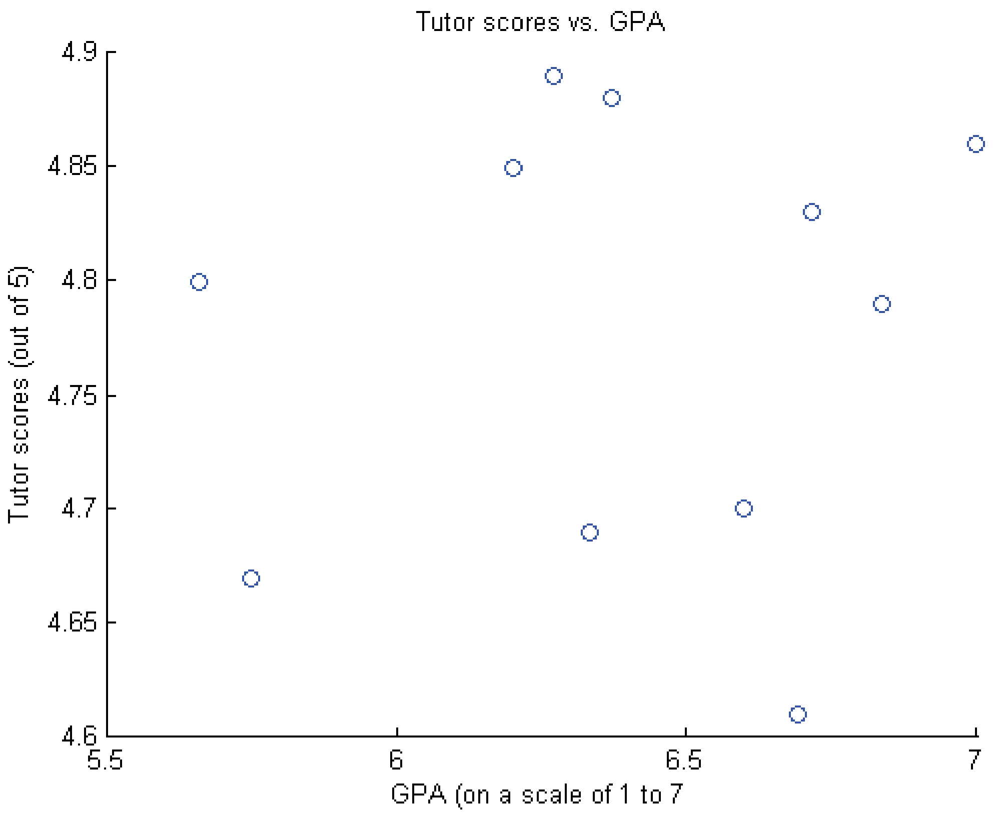

Figure 1. Scatter plot of Grade Point Average (GPA) vs. overall tutor evaluation score.

Tutor training

Two focus groups were organised in Semester 1, 2017 to extract findings on the tutor training scheme used in ENGG1300. One was a focus group comprised of tutors and the other was a focus group comprised of students. Both focus groups were moderated by the ENGG1300 unit co-ordinator.

The central themes emerging from the focus group for tutors were:

- seeing the example of other tutors was very helpful to improving as a tutor,
- feedback (mentoring) from other tutors was very helpful for improving as well,
- the academic mentoring provided via guided lesson plans was helpful,
- the tutor team worked very well together with very few conflicts,
- empathy (being able to step into students' shoes) was pivotal to being successful as a tutor,
- the micro-teaching was liked by most but not all tutors. Some tutors possibly did not like it because it was confronting to see oneself on video.

The key themes emerging from the focus group for students were:

- the students believed all of the tutors did a good job,
- the tutors helped to clarify concepts presented in lectures with good explanations,
- having two active learning sessions a week was very good for reinforcement of learning,
- the tutors in ENGG1300 were better than tutors in other first year units,
- the tutors were good at relating the maths inherent in electrical engineering to the real world.

The university's end of semester unit evaluation system provides students with the opportunity to provide free-form comments about all aspects of the unit, including the tutors and their performance. They are prompted to give free-form comments with the questions:

- "What were the best aspects of this course?", and
- "What improvements would you suggest?"

In the previous three semesters there were a total of 275 students who responded to the university's survey. There were 38 explicit comments about the tutors and 37 of them were positive. The one negative comment suggested the tutors could improve by engaging students in more discussion on practical issues in electrical engineering. A sample comment was "The tutors were really great and approachable and probably the most helpful tutor out of any of my courses".

There were also 81 explicit comments about the active learning sessions run by the tutors and 80 of these were positive. These comments typically pertained to the active learning sessions being helpful for consolidating learning. The single negative comment suggested that the sessions could be more interactive.

Conclusion

A strategy for enhancing tutor quality in a large first year engineering unit has been devised, implemented and tested. The strategy involves using recruitment and training processes that are evidence based and known to have high effect sizes. The recruitment consists of prioritising the selection of students who i) can demonstrate good teaching (either from past tutoring or via a set task in an interview), ii) have high general cognitive ability, iii) are conscientious and iv) are able to perform well in structured interview questions. The training involves i) microteaching, ii) personal mentoring of senior tutors by academic staff and iii) personal mentoring of junior tutors by senior tutors.

The scheme has been found to be successful according to both quantitative and qualitative measures, with the average tutor evaluation scores from students being 4.77/5.0 in 2017. It has also been judged to be qualitatively successful based on the findings of two focus groups and student comments in independent university based student evaluations.

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What can be learned from the humanitarian successes and failures of Thomas Edison

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CONTEXT

Engineers often find themselves in positions of leadership where they are able to influence others. While in these positions it is important that they seek to advance not just technology but also the social good. This paper critically examines the social enterprise efforts of one of history's greatest engineers, namely Thomas Edison, to see what lessons can be learned from him. In particular, the paper looks at three case studies where Edison tried to create increased opportunity for others. The first involves Edison's efforts to help the poor by building low cost housing for them, the second revolves around his efforts to improve educational outcomes for children and the third pertains to his mentoring of others.

PURPOSE

When one engages in humanitarian endeavours it is important to do so in an informed way. This paper looks at the efforts of one of the world's most successful engineers and asks the question: Why were some of Edison's social enterprises successful and why were some failures?

APPROACH

In each of the three case studies the outcomes are examined to determine whether or not Edison met his social objectives. Then the outcomes will be held up to the light of evidence so as to determine why some of the initiatives succeeded and some failed.

RESULTS

The evidence suggests that Cognitive Strategy Scaffolding (CSS) is one of the most effective ways for developing generic skills. This involves identifying experts in a target skill, abstracting their cognitive strategies, and then using prompts to repeatedly engage with those expert strategies. An examination of Edison's life reveals that Edison instinctively grasped the importance of the CSS approach and he often practiced it. This paper will argue that this is a key reason why so many of his initiatives (both technical and social) were successful. The paper will also suggest, however, that Edison sometimes used quite ad hoc approaches in his endeavours and failed when he did this.

CONCLUSIONS

Humanitarian engineering, like all engineering, tends to work best when it is pursued with evidence based practices. The life of Thomas Edison lends support to the notion that humanitarian endeavours can benefit enormously from the evidence based paradigm of cognitive strategy scaffolding.

KEYWORDS

Edison, social enterprises, cognitive strategy scaffolding.

Introduction

Creating increased opportunities for others is a significant and worthwhile goal but it is also a challenging one. To navigate this challenge it is important to investigate and pursue evidence based strategies. The skill of being able to create increased opportunity for others is an ill-defined one and as such, it tends to be fostered well with cognitive strategy scaffolding (CSS).

CSS has been found to be one of the best possible approaches for developing ill-defined (or generic) skills (Rosenshine, 1997). It involves three key steps:

1) Find experts in the target skill and isolate the cognitive strategies they use as they exercise their skill.
2) Devise prompts which can facilitate engagement with the cognitive strategies determined in Step 1. The prompts can be such things as checklists, targeted questions, pertinent analogies, guided reflections, physical models, examples, think aloud protocols, well thought out routines and programs, etc.
3) Practice the cognitive strategies from Step 1 with the aid of the prompts devised in Step 2.

In identifying experts in the field of creating increased opportunity, it is hard to ignore Thomas Edison. A 1997 issue of *Life Magazine* named him as the most influential person of the previous 1,000 years. This honour was bestowed on him largely because of the way he transitioned society from the steam age to the electrical age. He birthed several new industries, including the Electric Power Industry, the Music Industry (with his invention of a sound recorder), the Film Industry (with his co-invention of the film camera) and he had a major influence on the development of the Automobile Industry. All of these new industries opened up career paths for multitudes of people.

Edison, himself, often (though not always) used the CSS approach to develop his skills. To develop his formidable powers of invention, for example, he used the three step CSS approach:

1) He intensely studied the cognitive and experimental strategies of William Faraday, the world's greatest experimentalist.
2) He used the documented experimental procedures of William Faraday as prompts which could engage him in grasping Faraday's cognitive strategies.
3) He repeated Faraday's many experiments to help with his expertise formation.

As will be seen, Edison also used the CSS approach in some of his humanitarian endeavours, though, not always. To illustrate this point, the paper considers three particular case studies from Edison's life, with these case studies revolving around his efforts to:

i) help the poor in America,
ii) improve educational outcomes for young Americans, and
iii) mentoring others to create increased opportunities.

The next section describes Edison's efforts in each of these three case studies. The subsequent section pulls together the lessons which can be learned from these case studies, while the section after that discusses the implications for engineering education. Finally, conclusions are presented.

Case studies from Edison's life

Case study 1: Helping the poor in America

Edison's many successes gave him the confidence to tackle numerous challenging problems. One of these problems was how to help the poor in the heavily populated New York City area. He believed that he could give the local people increased opportunities by creating low cost housing for them. Edison did not seek to make a profit from this venture, rather he did it simply to improve the lot of the poor.

Edison expended huge amounts of personal effort on the project and devised an ingenious construction scheme which involved a single concrete pour rather than creating many smaller structures and assembling them together (Dyer and Martin, 1910). The houses built with this process were made available at about one third of the usual cost. Edison and his associates successfully assembled 11 of these houses in New Jersey.

While the housing project was a technological success, it failed dismally in its attempt to help the poor. The houses did not sell, as no one seemed to want the stigma of being "rescued from squalor and poverty" (Peterson, 1996). Because the houses did not sell, the project was also a significant financial failure. The large outlay for the new equipment needed to construct the houses was not recouped.

Case study 2: Creating increased opportunity by improving education

As a young boy, Thomas was declared by his teacher to be muddle headed. His mother became alarmed at the teacher's attitude and decided that Thomas needed a teacher who believed in him. She therefore decided to educate him herself (Edbiog, 2017). Her efforts in teaching Thomas were very successful, and he was very grateful. Towards the end of his life Edison publicly stated that:

"My mother was the making of me. She was so true and so sure of me and I felt I had something to live for and someone I must not disappoint".

Edison believed that his opportunities in life arose from the education he received at the hands of his mother. He in turn sought to create these kinds of opportunities for other American children. He was greatly inspired by Maria Montessori, a woman who abandoned a successful career as a medical doctor to work with unruly young children in a poor area of Rome. Montessori was an enormously successful humanitarian role model who helped many children. For her efforts, she was thrice nominated for a Nobel Peace Prize - in 1949, 1959 and 1951.

Montessori, herself, built up her humanitarian and educational skills via the CSS methodology. She started working with mentally handicapped children and to inform her work she carefully studied the work of the most inspiring experts she could find – Jean Marc Gaspard Itard and Edouard Seguin. Itard was the French doctor who took on the extraordinary challenge of trying to rehabilitate the so-called 'wild boy of Aveyron'. This boy had been raised in the wild from about 5 years of age till about 12. Seguin continued Itard's work with handicapped children, and in the process developed many hands-on materials which served as prompts for learning. Montessori started using the same types of prompts but then created many new ones of her own. The children in Montessori's classes repeatedly engaged with these prompts until they came to 'Ahaa' moments characterised by deep learning. Montessori eventually found that these prompts worked well with non-handicapped children as well, and she filled her classrooms with them.

Inspired by his own experiences with his mother, Edison was motivated to increase educational opportunities for children. To realise this vision he enlisted the services of Montessori, whom he recognised as an expert. Along with Alexander Graham Bell and

Woodrow Wilson, Edison invited Montessori to come to America. When she came she articulated and promoted her cognitive and educational strategies. The reception within America was mostly positive and Edison and Bell responded by financially supporting the establishment of Montessori schools and training bodies. Bell even set up a Montessori classroom in his own home.

The Montessori educational system was well received in America initially, but for a time it fell out of favour. The loss of openness to the system was due to the fact that some influential American academics waged a campaign to discredit the work. In the long term, however, the Montessori schools grew in popularity and were found to punch well above their weight. A study published in *Science*, for example, showed that the Montessori schools in America were outperforming conventional schools in both academic achievement and social skill development (Lillard and Else-Quest, 2006).

Ultimately the Montessori system had a significant impact on Engineering innovation, just as Edison and Bell had envisaged. This was the finding of a six year study on innovation by Dyer and Gregerson. That study identified Montessori schools as the pedagogical approach which seemed to be most successful at producing highly effective entrepreneurs (Dyer et al, 2009). Two of the three most valuable companies in the world (*Google* and *Amazon*) were founded by Montessori alumni. Moreover, the *Google* founders, Larry Page and Sergey Brin, have publicly claimed that their Montessori training was the reason they were able to achieve so much success.

Case study 3: Mentoring others to create increased opportunities

Edison himself contributed to the birthing of three new industries which opened up many opportunities for others. Edison also mentored others who went on to develop new industries of their own. The most notable of these mentees was Henry Ford, who developed the Automobile Industry.

Ford, like Edison, developed his technological expertise by using a CSS approach. Ford was in awe of Edison, just as Edison had been in awe of Faraday. Like Edison, Ford assiduously studied the approaches of his role model and applied them. Unlike Edison, however, Ford was able to study the cognitive strategies of his mentor at close range. He went to work for Edison when the opportunity arose, so that he could benefit from close personal contact.

Ford soon began doing experiments with gasoline engines and Edison heard about these experiments. Edison then approached Ford and asked him to give him some details on his work. After Ford outlined his plans, Edison banged his fist on the table and told Ford that he had a great idea, particularly as Ford's car would carry its own power plant.

Ford was tremendously energised by Edison's words and later claimed that:

"That bang on the table was worth worlds to me. No man up to then had given me any encouragement. I had hoped that I was headed right, sometimes I knew that I was, sometimes I only wondered if I was, but here all at once and out of a clear sky the greatest inventive genius in the world had given me a complete approval. The man who knew most about electricity in the world had said that for the purpose my gas motor was better than any electric motor could be—it could go long distances, he said, and there would be stations to supply the cars with hydro-carbon. That was the first time I ever heard this term for liquid fuel. And this at a time when all the electrical engineers took it as an established fact that there could be nothing new and worthwhile that did not run by electricity. It was to be the universal power."

Ford continued to shadow Edison and absorb and practice his cognitive strategies. Ford even bought a property next door to Edison in Florida in his later years so that he could spend time with him. The two properties are preserved today as a tourist attraction known as the Edison-Ford Winter Estate. Eventually Ford followed Edison's example by establishing a new industry - the Automobile Industry which became an industrial juggernaut.

Lessons to be learned

Consider first Case Study 1. It is pertinent to wonder why a man who could impact so heavily on the world at large failed in the seemingly simpler task of creating opportunities for the poor in New York. The answer may well lie in the fact that Edison was often successful when he used evidence based practices (such as cognitive strategy scaffolding) and he was often unsuccessful when he did not.

Edison failed to carefully study the strategies of any humanitarian engineering experts before venturing out as he did. Rather he simply used his ‘gut instinct’. Sadly, this instinct proved inadequate. Edison’s cognitive strategy for creating opportunities for the poor was to use his engineering ‘know-how’ to provide affordable housing which would free up disposable income. That is, he sought to directly change their socio-economic status. In hindsight it is not too hard to see that this was a flawed approach. The evidence suggests that socio-economic status has a substantial impact on peoples’ achievement, with a reported average effect size of 0.57 (Hattie, 2008). It is, however, quite difficult to change directly. Cognitive strategy scaffolding, by contrast, has an effect size of the order of 0.74 and can be engaged directly (Hattie, 2008). Edison failed to adopt evidence based approaches and failed.

In contrast to Case Study 1, Edison’s efforts in Case Study 2 demonstrated much better engagement with evidence based processes. Edison wanted to advance education and so he sought out one the world’s foremost experts – Maria Montessori. He then parlayed her strategies into the fabric of American schools. Edison’s vision for creating increased educational opportunity bore fruit in the long-term, in spite of the discrediting efforts of powerful adversaries.

In Case Study 3, as in the earlier studies, the CSS methodology proved to be important. Henry Ford copied the example of Edison and used CSS to develop his expertise. He shadowed Edison throughout his life, working with him, socialising with him and even buying a house next to him so that he could see and learn from his mentor’s thinking strategies.

Implications for Engineering Education

The aforementioned case studies suggest that CSS is a very successful approach for developing generic skills, including skills within the humanitarian arena. It would seem advantageous if this this kind of approach could become normative in universities. How, then, could this be achieved?

One of the most obvious educational paradigms employing the CSS approach is the Montessori system. Transferring the principles used in Montessori education to universities, then, would be a good first step to fostering the CSS approach. As discussed in (O’Shea, 2017; O’Shea and O’Shea, 2011), there are a number of key principles underpinning Montessori training and almost all of them can be translated (to some degree at least) into university level training. An explicit example of using the CSS approach (for reflective design) is also provided in (O’Shea and Kearney, 2016).

Conclusions

A key common element in Edison’s various successful attempts at creating enhanced opportunities for others was the use of cognitive strategy scaffolding. This approach has been shown to be effective for generic skills development in general and the case studies from Edison's life show it to be effective for initiatives to create increased opportunities for others. It is concluded that cognitive strategy scaffolding should be used more in the training of engineering, particularly for the purposes of increasing opportunities for the disadvantaged.

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What Difference Do the Differences Make: Cultural Differences as Learning Resources in a Global Engineering Course

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CONTEXT Over the past two decades, engineering educators and researchers in higher education have witnessed a growing emphasis on the intercultural competency for engineering graduates, due to the globalization in the market and workplace (Downey et. Al. 2006; Grandin & Hedderich, 2009; Valtaranta, 2013). In response to such reality, colleges and universities have initiated numerous technology-enabled intercultural programs and leveraged the task-based team activities to enhance intercultural exchange (e.g., Korhonen, 2002; Cajander, Daniels, & von Konsky, 2011). Nevertheless, the dominant discourses in this field tend to be framed by political, economic and organizational perspectives, with limited efforts devoted to understand educational experiences that students will go through in those courses and programs. Therefore, more attention should be paid to “the intercultural meetings and cultural content in education” and how to make that happen from a curriculum perspective.

PURPOSE By examining what and how students had constructed while engaging in an intercultural activity in a global technology-enabled engineering course, the research examines how the curriculum design supported or constrained opportunities of intercultural exploration in a global context.

APPROACH The study is situated in an ongoing four-year ethnographic project guided by Interactional Ethnography approach (Green, Skukauskaite and Baker, 2012; Castanheira, Crawford, Dixon, & Green, 2001). Data collected for the study include video records of classroom interaction, artifacts made by groups and instructors, filed-notes and interviews. The collected data was analyzed via ethnographic and discourse analysis.

RESULTS Firstly, it identifies that three groups of students, when provided a same task prompt, differed in multiple dimension in the group assignment, not only in contents and formats of presentations, but also ways of negotiating, making decisions and collaborating in preparing the assignments within the groups. Secondly, it finds that students extended and reformulated understandings of other cultures after contrasting the three presentations, and adapted effective ways of group working from other groups. Thirdly, it identifies that the transformations in student understandings and actions were made possible by the instructor’s curriculum design, including designing of the tasks as well as the structure of the class activities.

CONCLUSIONS The research provides an evidence-based inquiry exploring how and in what ways the instructor’s curriculum design created and shaped opportunities of intercultural learning in global engineering education practice. The learning evidence along with the identified transformation in student understandings shows that to support the intercultural learning in engineering education, it needs instructors to carefully and deliberately design the learning activities and opportunities.

KEYWORDS engineering education, cross-cultural communication, educational ethnography

Introduction

Nowadays, U.S. engineering programs are undergoing a shift from a traditional focus on "hard" technical skills, to an additional recognition of "soft" cultural skills, especially intercultural communication competency. Important initiatives have been made in the engineering curriculum, including the coursework requirements that students take foreign language and general education courses with an emphasis in international aspects and participate in study/work abroad programs. For example, Downey et.al. (2006) report a course titled *Engineering Cultures* as an effort to integrate global learning into classroom experience at Virginia Tech and the Colorado School of Mines, which was designed to engage larger numbers of engineering students to take the critical first step toward global competency. These studies, along with more recent ones (Van Maele, Vassilicos, & Spencer-Oatey, 2013; Hahn, & Sorenson, 2014; Deardroff & Deardorff, 2016), have provided practical guidance and suggestions for promoting intercultural competency among engineering students.

Literature review suggests some tensions within the intercultural initiatives. Ciftci (2016) in a literature review of computer-based intercultural learning suggests that the majority of current intercultural programs are fact-based, and sometimes superficial, in which students mainly exchange factual knowledge of different cultures and fails to maximize the opportunity to foster in-depth dialogues. Meanwhile, current research on intercultural education is usually outcome-oriented, focusing on the valuation and assessment of student development of intercultural competency. Guided by the orientation, a number of assessment models and frameworks have been developed, while limited research has been developed to focus on the enacted curriculum, examining the process how learning happens and students develop their intercultural understandings.

To bridge the research gap, this study presents a curriculum analysis of an intercultural learning task in a global technology-enabled engineering course that was jointly participated by three teams of students located in USA, Mainland China, and Taiwan (n=60). Focusing on the process of team tasks presented in the class, it explores how these three teams of students, when provided a common task statement, differed in ways of taking up the task, and how such differences in teamwork practice became resources for students to reformulate their understandings and actions in subsequent activities. Based on the empirical evidence, it examines how the curriculum design supported or constrained opportunities of intercultural exploration in a global context. Methodologically, the study is guided by an ethnographic perspective and adopts discourse analysis to trace the learning process. It provides an evidence-based inquiry exploring how and in what ways the instructor's curriculum design, including the task design and the course structure, created and shaped opportunities of exploring intercultural communication in global engineering education practice.

Research Design

Research setting

The study was conducted in an undergraduate engineering course Principles and Practices of Global Innovation in a global educational program called the iPodia Alliance (http://ipodia.USU.edu/) in 2016, which involved three globally distributed research universities in US, Mainland China, and Taiwan (USU, CHU, and TWU). To attend the course, students, who gathered in their local classrooms on their own campuses, were connected by the videoconferencing technology in a *World-Classroom* in which they attended lectures simultaneously. The lectures were delivered by the instructor who was physically located in the American classroom. The subject matter of the 14-week course was engineering design thinking from a socio-technical perspective. Its critical argument was that designers must synthesize various social and technical factors to create functional artifacts (or service) that can satisfy customer needs (Jing & Lu, 2008) since social and cultural factors shaped customer needs while technical factors decided practical feasibilities. To help students understand how to explore the culture of a market, the instructor designed two intercultural activities along the quarter.

The present study focuses on the second intercultural activity titled *An Extraordinary Description of an Ordinary Day on Campus*. Guided by an ethnographic view of culture as socially and interactively constructed in everyday life, this task aimed to engage students in reflecting upon their everyday practice and exploring how the local culture was constructed in and through social interaction, as a preliminary step for future investigation on the culture in a foreign market. As requested by the task, three teams were formed by school and each team prepared 10-minute presentations for detailed and situated descriptions about their daily activities in a micro-level. On the day of presentation, the class section was structured into three parts. Firstly, each of the three teams took turned to have their team presentation. After that, the technical staff cut off the videoconferencing connection among classrooms for the 30-minute in-team discussion, in which they identified differences and similarities that were made visible about campus lives from the three previous presentations. Then, three classrooms were reconnected, and each team had a 10-minute response to present their findings.

Participants

The study (as well as the course) was participated by 60 lower-division undergraduate students from three universities in U.S., Mainland China, and Taiwan, with 20 from each university. As shown in Table 1, while USU students were exclusively from engineering and business backgrounds, CHU and TWU students were more diversified in academic backgrounds, including engineering, science, social science, humanity, and arts.

Table 1 Discipline Backgrounds of the Participant Students in the Study

	Engineering	Science	Social science	Humanity and arts	Total
USU	15	0	5	0	20
CHU	6	2	7	5	20
TWU	7	2	7	4	20

Research method

The research is guided by an international ethnographic (IE) approach (Green, Skukauskaite and Baker, 2012; Castanheira, Crawford, Dixon, & Green, 2001). This perspective focuses on artifacts and actions associated with language-in-use and provides a systematic and empirical way to record, analyse, interpret and report understandings constructed through social interaction within a social group. Unlike the quantitative methods verifying theories in a deductive way, it is an iterative, recursive and abductive reasoning process with an ultimate purpose to understand the insider's perspective. Guided by the IE approach, this research grounded the inquiry of curriculum on the task construction and social interaction in the class. Based on that, it explored what knowledge and understandings had been constructed and made visible.

Multiple methods were used to collect qualitative data, including field observation, class interaction videos, student interviews. The analysis followed a typical ethnographic research cycle, which consists of asking questions, collecting data, making a record, and analysing these data (Spradley, 1980). Generally speaking, the analysis starts with a summary description of activities happening within the context, then moves into more focused explorations of certain segments that might shed light on the research question, and finally to the more micro-level analysis of selected segments of observed interactions. To answer the research question, this research began at a general level of observation of the class interaction and gradually narrowed in how a particular activity (as well as a segment of the assignment) was constructed (Spradley, 1980; Gumperz, 1982). Through the analytical approach, two kinds of data tables are created: an event map and a transcript. An event map represented phased and themed activities constructed by participants, while a transcript showed the moment-by-moment interactions among participants as they acted in a concerted way to achieve these activities. By using these two kinds of the data table, researchers were able to develop a comprehensive as well as in-depth understanding of students' task construction.

Findings and Discussion

Based on the analyses, the research findings are presented in the following two subsessions.

A same task, different take-ups

The field observation reveals that three teams of students, when provided a same task statement, delivered their own presentations that differed in multiple dimensions. In terms of the presentation format, USU students presented a PowerPoint slideshow, while the other two teams chose non-traditional formats: CHU students played a short movie to manifest their project, and TWU students presented a stage show in which students as actors acted out their project as if telling a story. The difference in format shows that each team had their own understanding of what counted as a presentation. While USU students held a regular view of a presentation as the business-style slideshow, CHU and TWU students appeared not to be constrained by the regular style, but creatively incorporating other media, format, and resources into the presentation. Beyond the presentation format, was in-depth difference reflected in presentation contents, including the content structures, their problem-solving strategy, and more importantly, the student learning.

Further analysis shows in-depth differences in the presentation contents. Table 2 summarizes the multi-level differences across the three presentations. In short, the NTU students presented a theatrical play supported by the linguistic, gesture, and spatial modes. In the play, they used narration to trace Ruby's, who was set as a typical NTU student, life routine across a day on campus. By unfolding Ruby's campus activities, it provided a detailed and situated description about the cultural practices on the NTU campus. As for the CHU students, they delivered an oral presentation and a movie as their assignment, which jointly used the linguistic, visual, and audio modes. In the movie, they created two characters as typical CHU students, Science Guy and Sunny Girl, and traced their experience across multiple settings on campus. By adopting the narration and comparison of rhetoric mode, they created situated description about their campus life as well as the problematical practices. Last but not least, the USU students did a PowerPoint presentation with linguistic, written, and visual modes. By organizing the content in a tree structure, they employed the division/classification rhetoric mode and exhausted student tools, options, and choices in the four dimensions of their lives, i.e., transportations, foods, academic life, and extracurricular life. Their description was oriented to a more comprehensive picture of student life by adding up the concrete options, while their view of student life went beyond the physical boundary of the university campus and included activities out of campus.

Table 2 Multifaceted differences of the Presentations across the three groups

	TWU	CHU	USU
Format	Theatric play	Remarks + movie	Slideshow
Mode	Language, gesture, spatial	Linguistic(oral), visual, audio	Linguistic, written, visual
Organization	Single tracing unit	Parallel contrast of two tracing units	Tree structure
Focus	Cultural practice	Customer needs	Tools, options, and choices
Rhetoric style	Narration	Narration, comparison/contrast	Division
What counted as extraordinary description	Detailed and situated description	Situated description with multiple manifestation and underlying reasons	Breadth and comprehensiveness, to exhaust possible options and add up
What counted as the ordinary campus life	A typical student's daily activity in typical settings on campus	Typical students' significant problems in living on campus	Student life in a daily basis, within and out of campus

What Difference Did the Differences make?

After the presentations, the instructor assigned the class for a 30-minute discussion section. For the discussion session, the videoconferencing connection across three classrooms was cut off, leaving each team to have discussion on their own. Each team had to identify some differences and similarities in campus activities from the three presentations. After that, three teams would be reconnected and present their team discussion outcomes and findings as a response. During the investigation of team discussion and responses, the differences made visible in previous presentations turned out to shape students' understanding and trigger two kinds of transformation.

The first transformation was evident in USU team's discussion. In addition to the differences and similarities, they also discussed how to present their findings. Table 3 is a transcript of an excerpt from the discussion:

Table 3 Transcript of A Segment of USU Team Discussion

Line	Speaker	Message Unit (Narrator)	Contextualizational Cues
334	Male	I say um we should make a 5-minute video right now	Class laughs
335	Female	iMovie!	High volume

Within this segment, a male student proposed to make a video, as CHU team did, for the incoming response and the class responded with laughter. The proposal to make a video reflects that USU students were aware of the difference, if not a gap, between their own presentation and the other two, and they appeared to want to learn from CHU team and present a video as well. Such self-awareness also can be seen in their following response as well, when a USU student opened their response by saying:

> *We noticed that apparently we, since we're all business majors, engineers in our team, that we aren't as creative (as our previous presenters). So we decided that we should add something to our slide show in our attempt to be more creative, as you guys.*

In this excerpt, USU team admitted that they were not as "creative" as other two teams, acknowledging a gap in ways of doing presentations. They further contributed the gap to their academic backgrounds of either engineering or business, which was believed to shape their particular ideas of presentations and constrain their creativity. To break the constraint and "be more creative", they changed their way of doing the response by incorporating a short live show, which they learned from TWU team. It is clear that, by contrasting the presentation done by others and themselves, USU team reframed their understanding of what counted as a presentation and how to deliver a good presentation. That is, students' understanding of the presentation was greatly broadened by new ideas and best practices. Inspired by these models, they reformulated their mindset and adjusted their actions in the consequent response.

Another kind of transformation in understanding can be seen in three teams' response, which was caused by the differences in campus activities shown in the three presentations. TWU's response can be used as an example to demonstrate such a transformation. In explaining what differences and similarities they found among three presentations, the TWU presenter said as following:

> *We try to discuss the unconsciousness part that lies the little clip shot by the CHU students, and the slides of USU students. Like in little clip, there are some part like, Science Boy try to ask for the seat, and the sunny girl also ask for the seat, and other parts like, the Science Boy after he ordered meal, he also tried to find a place, and also like the sunny girl dancing on the platform of the metro, and these points are indicating that PKU students have needs and demands under their consciousness part of their brain, to seek for the space in their life, in their campus life. They're trying to find space, or the demand, or the X in the clip, are related to these kinds of wants in their daily life. We think about that's what we got for CHU students. And comparing to TWU students, we think that we also have this kind of situation on our campus. Since we have so many students also on our campus, we do have limited space, so we want for more space for our personal space. But compared to CHU we are freer, we do not have obligation or regulation, that we could not have activity in some building in some places, outside, inside the campus, or we do not have the regulation that we need to go to bed at 11. Without the regulation, we have more freedom, or the right to use the space on our campus. So compared to CHU students, although we also have this kind of problem, we have more flexible in this issue.*

In this excerpt, the presenter cited specific activities from presentations as evidence to support their observation that CHU students were "seek(ing) for the space in their life". These activities were carefully selected and reframed to fit into their central claim about the physical space problem. Based on the concrete evidence, he directly pointed out the inference and interpretation made by his team: CHU students had needs on space. The word choice, "under their consciousness part of their brain", indicated that the TWU team attempted to go beyond the surface of these activities and extract some essential understanding about CHU campus. The attempt was successfully achieved when he removed all these superficial differences in detailed activities between CHU and TWU and identified a shared problem in an abstract and essential level, the space issue. In addition to the similarities, he further identified differentiated reasons underlying the phenomenon. That was, even there was insufficient space in TWU campus, they did not have "obligation or regulation" that constrained students' usage of space as CHU did. By building connections across campus lives and reading beyond the surface, they advanced their understandings about cultural differences and developed in-depth understandings of essential reasons underlying these differences and similarities.

Similar advancement in understandings could also be found in CHU and USU teams' responses. For example, CHU figured out the growing awareness of privacy among this generation of college students as one of the essential reason for the space problem. As shown in the above analysis, the advancement in understandings was made possible by the previous presentations, in particular, the differences in presented activities. From this perspective, these presentations, like a collection of library references, provided rich resources for students to contrast and reflect upon, so they could go beyond the concrete activities and develop deeper understandings about the cultures and cultural differences.

The transformations presented above, make visible how the curriculum design and course structure with three phases of activities-- presentations, discussions, and responses, created the possibility for reformulation in understandings and actions. The presentations were not only to present the final products of teamwork that happened before the class section but to also provide a starting point for engaging students in the practices and processes of exploring the similarities and differences in ways of doing presentations and campus-based activities across teams. From this perspective, as three teams unfolded their work in presentations, these presentations became public texts for interpretation, constituting new(er) contexts of the class. By observing what other teams were doing and where, when, and with whom, students (re)framed their discourses, adjusted their decisions, and (re)formulated their actions in consequent events, in order to match the changing context. In this sense, students in interaction became environments and contexts for each other, and they shaped and in turn were shaped by the context being constructed (Erickson & Shultz, 1981).

Discussion

This study presented a curriculum analysis of an intercultural learning activity in a global engineering course. By examining the assignment presented by the three teams, it identified different practices and understandings constructed by students in doing the task. Based on that, it further explored how the instructor turned the difference in taking up the given task into a new opportunity for learning. That is, the differences in doing the presentations and the different contents of campus activities presented in the presentations, were used by students as resources to reformulate their understandings and reframe their consequent actions. By uncovering the practice and process of student engagement in the designed activities, the study shows that the curriculum design supported student learning and exploration in intercultural communication.

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Application of Research Skill Development (RSD) in Sustainable Engineering Teaching and Learning

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SESSION

C3: Integration of teaching and research in the engineering training process

CONTEXT In the offering of CHE3163 Sustainable Processing 1 for 3rd year Chemical Engineering students in Monash University Malaysia, an LCA software, GaBi was introduced for the first-time in 2017. It was part of the effort to introduce research-led approaches and up-to-date knowledge using technology-enhanced engagement. As part of the assignment question, GaBi software for advanced LCA analysis was introduced to study electricity generation using renewable and nonrenewable options. Through collaborative efforts with librarians, the research skills development (RSD) workshops have been integrated to assist the students with self-directed learning of new software for their LCA assignments.

PURPOSE How to embed the research skills amongst the students when dealing with their assignment?

APPROACH The RSDf workshop with a few activities were conducted. During the workshop, students were introduced to the RSD framework as well as linking it to the LCA assignment given. Students' feedback on the RSDf workshops collected and analysed. Both quantitative and qualitative questions were provided to participants.

RESULTS The closed ended survey results 75% stating the workshop was good or excellent, they enjoyed the opportunity to work with classmates, and the workshop developed their understanding of how they could apply the RSD to self-directed learning when conducting the LCA assignment.

CONCLUSIONS RSDf has enhanced students' research skills when conducting assignments, i.e. learning of new software in this context.

KEYWORDS Sustainability, engineering education, Research Skill Development (RSD), teaching research linkages, undergraduate research.

Introduction

Assignments are integral part of many undergraduate courses and often used as summative assessments to gauge the student's performance. The assignments are carefully designed by the educators to enhance specific set of skills required by the students as per the course syllabus. The required skills vary from problem-solving to public-speaking, depending on the nature of the courses and degrees offered. However, most of the assignments will require the students to begin the task by 'researching' about the problem at hand. Interestingly, the ability to carry out the required research on the task assigned can be further enhanced by exposing the students on the framework known as 'research skills development' (RSD).

The RSD framework is a conceptual model that provides an explicit scaffold and precise building blocks for the student to develop their research skills (e.g., information literacy, academic writing, critical thinking; Willison & O'Regan, 2007). The RSD framework was developed by researchers at the University of Adelaide (Willison & O'Regan, 2007) and represents a conceptual framework that assists academics and staff to develop academic curricula that explicitly develop research skills for their students.

Research and communication skills need to be fostered over several years and students will benefit most from this if the RSD framework is clearly defined through their assignments and they are made aware of the progression they will encounter from the first stages of the degree through to graduation (Burkill, 2009).

The RSD delineates the skills associated with research into six facets: embark on research and clarify understandings needed; find information and generate data; evaluate information and data, and reflect on processes used; organise information and manage processes; analyse trends and synthesise new understandings; and communicate and apply understandings and processes ethically. These six facets are elaborated into five levels of student autonomy, with Level 1 being Prescribed Research and Level 5 being Open Research (Willison & O'Regan, 2007). The student autonomy is determined based on the degree of input provided by the instructor when assigning the task, either through step-by-step approach, restricted degree of guidance or fully open-ended.

The RSD can also be used to introducing students to necessary aspects of research processes; and for analysing teaching, learning and assessments elements in curricula. (Willison & Buisman-Pijlman, 2016). A multi-institution study showed that use of the RSD framework could effectively help individual educators and small teams to design semester-length courses that developed students' discipline-specific research skills in many disciplines and year levels (Willison, 2012). The RSD framework is also useful in assisting staff to develop assessment rubrics that explicitly state the skills required to succeed in an assessment task.

The importance of research skills is established as mentioned above and can be taught through RSD framework to students. In the offering of CHE3163, students were required to use a new life cycle assessment (LCA) software known as GaBi. This is a free educational software with user-friendly features. Students needed to carry out their assignment with the software and compare their experience without the LCA software. In learning the software, students needed to apply self-directed learning through various research skills. The scope of work in this paper focuses on students experience in learning research skills through 'research skills development' (RSD) framework workshops.

Approach

The 2-hours RSD workshops were designed and conducted. It has been previously shown that collaborative learning environments help improve students' critical thinking and reasoning skills (Collier, 1980; Dunne & Bennett, 1990), particularly if peer learning is directly associated with an assignment (Boud, Cohen, & Sampson, 2001). Consequently, the workshops were designed as an interactive class where group discussion was used to analyze the assessment task and decide how to best approach the LCA assignment. Small workshops are usually better for problem based learning, as they promote discussion and higher order cognitive reasoning skills (Boud et al., 2001; Collier, 1980; Dunne & Bennett, 1990).

The classes were conducted in two workshops of 42 students and 15 students, respectively with five staff members present: two academic staff, two librarians, and one research assistant. Two librarians facilitated the workshops, providing students with activities for discussions on RSD and the academic staff facilitated the discussion on linking LCA assignment with RSD skills. The activities included: (1): students to discuss and draw their interpretation of a ‘research savvy’ student; (2) students to read a press release about ‘Facebook is closing down’ and explain why they trusted or distrusted the press release’; (3) students were given a set of six colourful cards, which each card assigned to one of the six RSD facets, and students to match the cards to the skills that they identified in other activities and (4) students to have discussions around the RSD placemat and how it can be used to support their assignments. Students were encouraged to work in groups during the activities and they were then asked to present their ideas to the workshop. All activities used in the workshops were designed to help students to derive the six facets of the RSD and were given to students in a logical sequence to help them in understanding the RSD. After attending the workshop, students were expected to be able to correlate the RSD with their research process and apply the RSD to improve their assignment.

During the workshop, students were introduced to the RSD framework as well as linking it to the LCA assignment given. The students were given the LCA assignment to evaluate the environmental indicators such as global warming potential, acidification and nutrification, associated with electricity generation options using renewable and nonrenewable options. Students needed to map the research skills that they learnt in the workshop by listing down the type of skills they needed to accomplish the LCA assignment and map them with 6 facets of RSD. Completion of LCA assignment primarily involved self-learning of a new software, known as GaBi. Students needed to apply the fundamentals learnt under LCA topic using the software to calculate the environmental indicators that were mentioned above. They were asked to brainstorm and present their findings during the workshop.

At the end of the workshop, the feedback from the RSD workshops were gathered through both close and open-ended survey questions. The close-ended surveys were run as a Monash Audience Response Survey (MARS) session and open-ended survey feedback was gathered through printed feedback forms.

Results and Discussion

Both quantitative and qualitative questions as shown in Table 1 were provided to participants. Fifty-seven students completed the feedback form after the workshops.

Table 1: Close-ended questions for RSD workshop

No	Question
1	The overall the workshop was
2	The content of the workshop was at the right level for me

3	The workshop was thought provoking
4	The content of the workshop is relevant to my learning
5	The workshop achieved the stated learning objectives
6	I enjoyed the opportunity to work with classmates/ in groups
7	There were sufficient opportunities to participate in this workshop
8	The workshop developed my understanding of how I could apply the RSD to LCA assignments
9	The workshop developed my understanding of how I could apply the RSD to self-directed learning when I conduct LCA assignments
10	The RSD workshop nudged me into learning ‘how to think” rather than “ what to think” and to unpack thinking processes
11	The workshop brought home the importance of my role in student autonomy / academic independence when I conduct the LCA assignments
12	The workshop provided me with a framework and space to strengthen career and lifelong skills in terms of sustainability in engineering

The feedback form comprised of 12 Likert-scale statements (i.e. quantitative questions) about the effectiveness of the RSD workshop activities included: “The workshop was thought provoking”, “I enjoyed the opportunity to work with colleagues from other areas across the university” and “The workshop developed my understanding of how I could apply the RSD to LCA assignments”. The Likert scale questions numbered 2-12 from ranged from (5) being strongly agree, (4) agree, (3) neutral, (2) disagree (1) strongly disagree; whereas question number 1 had a scale of 5(Excellent), 4(Good), 3(Fair), 2(Could be better) and 1(Poor). The quantitative survey containing the Likert-scale questions feedback form was run as a Monash Audience Response Survey (MARS) to increase engagement and the number of responses.

Table 2: Open-ended questions

No	Questions
1	Something new I discovered was ……………
2	Something I would like to know more about is …………..

3	Would you recommend this workshop to friends?
4	Any other comments?

Students were also given open-ended questions through printed feedback forms as listed in Table 2. The open–ended survey questions were further evaluated along themes of responses and its significance.

The Likert-scale questions survey (Table 1) results approximately 75% stating the workshop was good or excellent (Q1), they enjoyed the opportunity to work with their classmates (Q6), and the workshop developed their understanding of how they could apply the RSD to self-directed learning when conducting the LCA assignment (Q9); results depicted in Figures 1, 2 and 3.

Figure 1 : Response to question on 'overall experience of the workshop'

The workshop comprising of various fun activities such as building a pyramid and drawing a 'research-savvy' student provided the engineering students to break-free from traditional class setting lectures and tutorials. Observations and informal feedback received from the students were positive, which contributed to 75% of class agreeing that the workshop was good or excellent. More than 60% of the participants also agreed to the statement 'The RSD workshop nudged me into learning " how to think" rather than " what to think" and to unpack thinking processes.

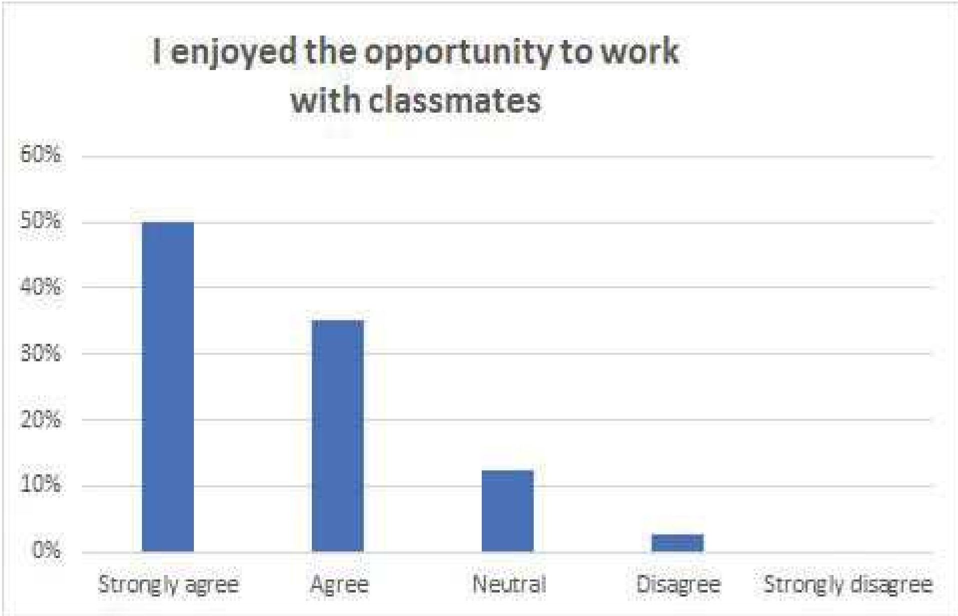

Figure 2 : Response to question on ‘working with classmates’

Some of them were introduced to new friends during the workshop and enjoyed the experience. Most importantly, the RSD framework unpacked important skills needed in planning the LCA assignment task. They brain-storm the LCA assignment and discussed on how to carry out the task using a new software. This also resulted in 75% of the class agreeing that the workshop helped them to apply RSD to self-directed learning of new software, GaBi. This free educational software is being introduced for the first time in offering of unit CHE3163 and posed students with new challenge of learning the software with minimal help from the tutorials conducted. Students are aware of traditional manual LCA calculations and required to apply the fundamentals when using the software.

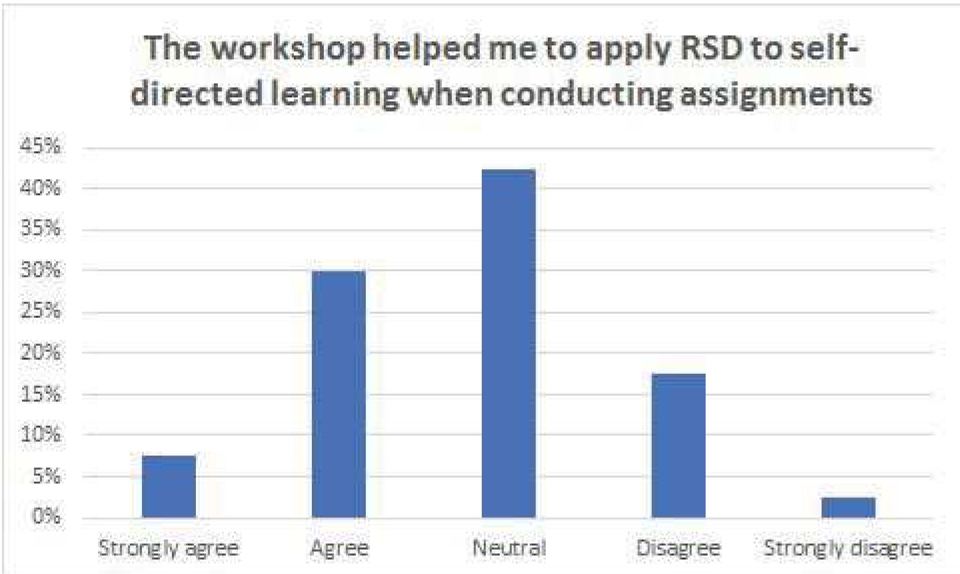

Figure 3 : Response to question on ‘self-directed learning’

The results of open-ended feedback (Table 2) is illustrated in the Pareto Charts and depicted as Figures 4, 5 and 6. The responses to the open ended questions were categorized according to main themes and Pareto Charts was generated based on the 80/20 principle.

The significant themes from "Q1: something new I discovered" were "awareness and applications of RSD, exposure and awareness, importance of self-autonomy".Other feedback received included "enjoyed the activities of the day, gained more knowledge and skills, importance of communication and importance of teamwork". Some of the interesting comments include : "*I have not researched well for my past assignments and I learned that there are many ways to research, evaluate and compose question"; "on how to apply RSD to my LCA assignment and student role in doing LCA assignment" and "the detail in which a project should be handled and the layers of depth in research for me to handle assignments through RSD".*

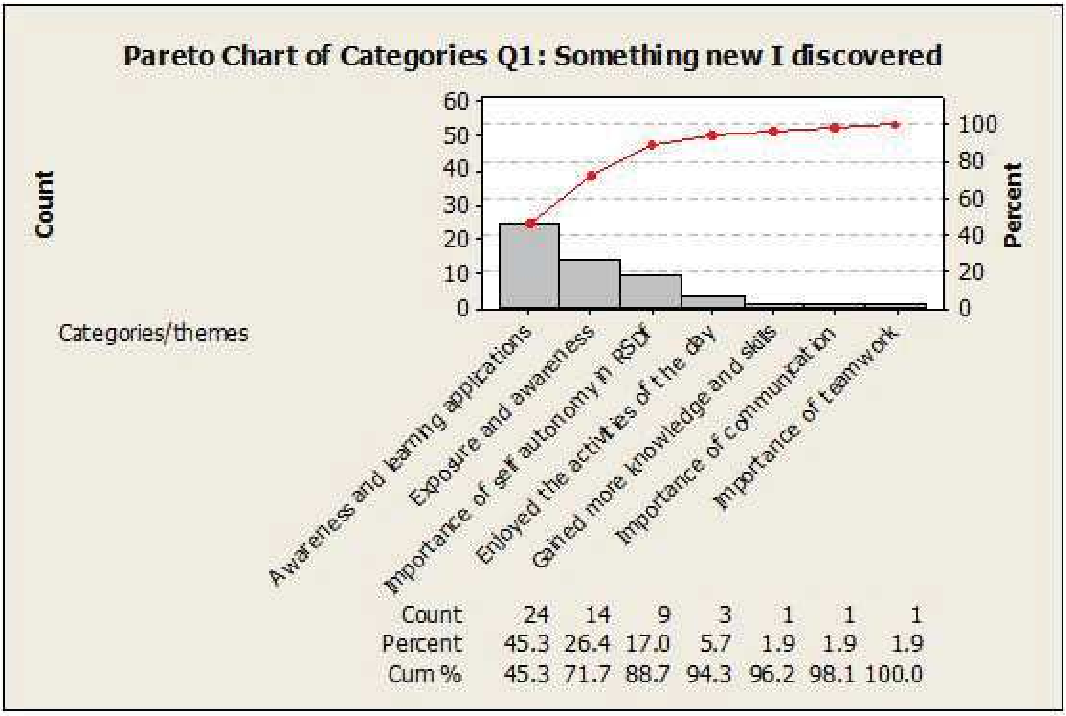

Figure 4: Response to Q1 according to themes and categories

As for question 2 ' Something I would like to know more about is" the significant themes that came through at 80% were "more on RSDf and applications", "awareness and applications" and less significant were the feedback on "other aspects" as can be seen on Figure 5. Some of the interesting comments are "how to do research in an efficient way" and 'the way to research the software". The second comment in the former sentence shows the gap in the workshop conducted in which there was no activity on linking RSD with the use of learning a new software. This is mainly due to the limitation of time for the workshop as well as no discussions were designed to discuss about the special features of the software. Such students' feedback is an important aspect to further improve the design of activities to brainstorm specifically on the software and RSD framework. However, discussions on how to carry out the overall LCA assignment after learning about RSD was carried out effectively. Students were also exposed to the marking rubrics designed specifically for the LCA assignment. The rubrics provided them with clear expectations on each grade requirement on different aspects of assignment such as LCA methodology, LCA indicator calculations, report presentation, and critical review of the environmental burdens calculated.

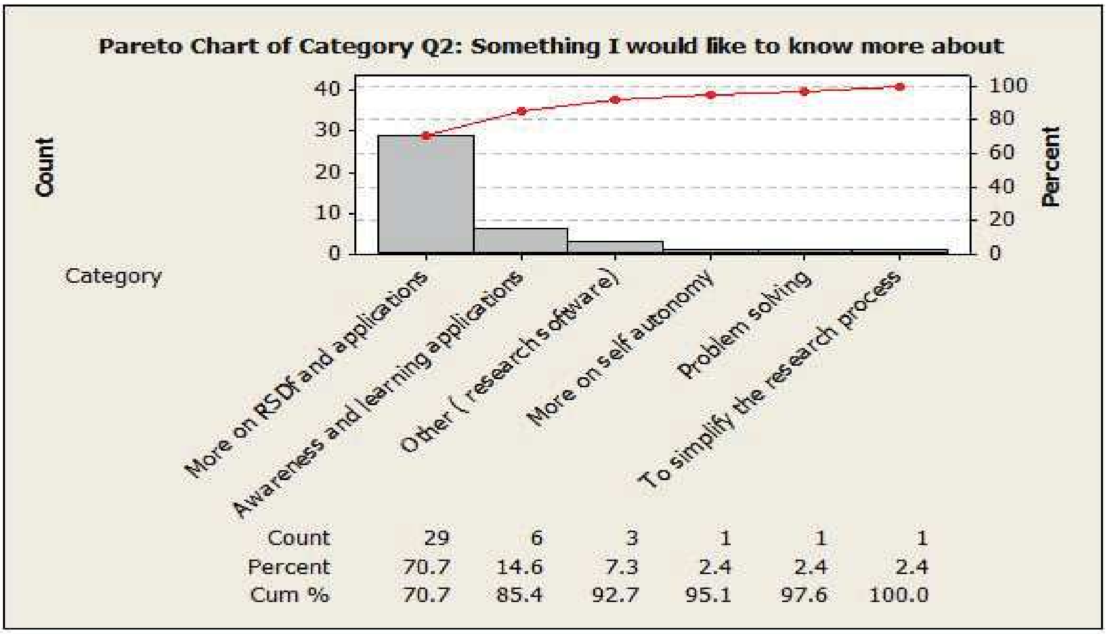

Figure 5: Response to Q2 according to themes and categories

As for the third question " Would you recommend this workshop" 84% said "yes'. 13.7 % were neutral and 2% said "No" as illustrated in the Figure 6 below. Most of them also added that it would be helpful if they recommended to their friends who are keen on research. This shows the significance of the RSD.

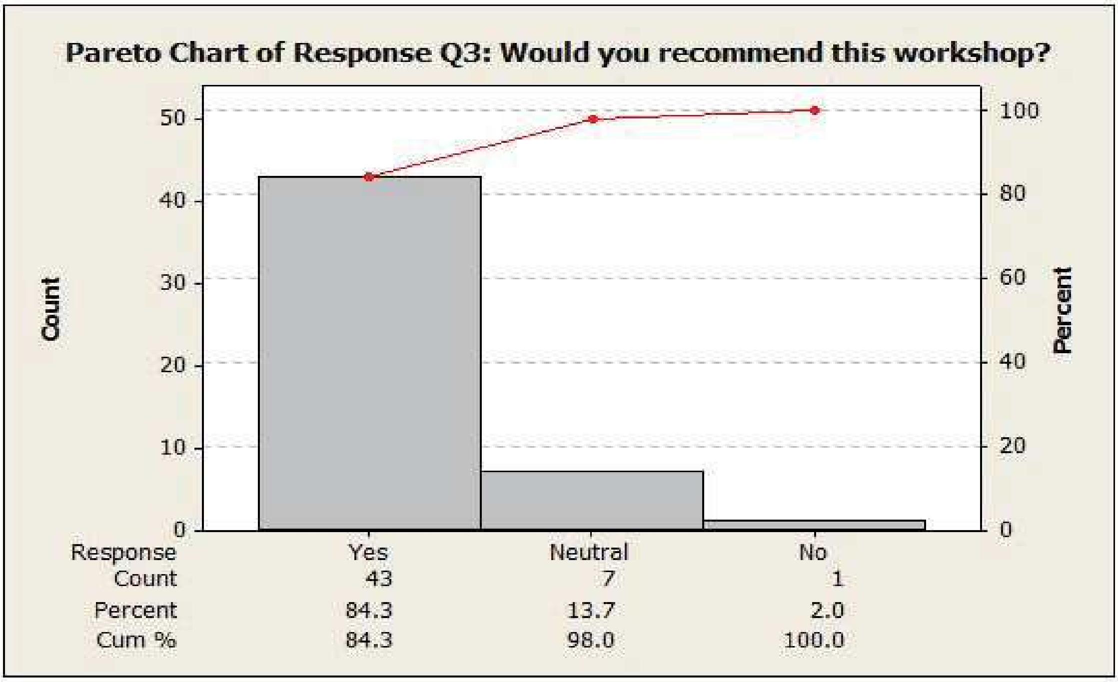

Figure 6: Response to Q3 on 'recommendation of the workshop'

Conclusions

It is evident from the quantitative and qualitative analysis that the RSD framework has enhanced students' research skills before conducting LCA assignments. Students benefited from learning six facets of RSD framework and clear about autonomy they have on their LCA assignment. However, the RSD framework can be applied in all assignments and research work. The development of the marking rubrics and discussion revolving around it during workshop has helped students to get clear directions on the expectation of LCA assignment.

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A "MetroGnome" as a tool for supporting self-directed learning

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SESSION C1: Integration of theory and practice in the learning and teaching proces

CONTEXT Charles Sturt University introduced a new engineering degree in 2016, with a strong focus on self-directed and –motivated learning. The outcomes of the first year of operation show that while some students are able to thrive in such an environment, the majority required significant scaffolding to work effectively in a self-directed environment. A tool was needed to balance the need for supporting students to become self-directed learners, without providing so much support that they become reliant upon the scaffolding and thus do not develop the necessary independent learning skills.

PURPOSE The investigation was whether the introduction of a "MetroGnome" for the students to benchmark progress against would provide a sufficient balance of scaffolding to develop self-directed learning.

APPROACH Each week the students are given a progress update for the MetroGnome – a garden gnome who lives in the student learning commons. In this way academics can provide a gamified benchmark for minimum acceptable progress to the students, without having to produce competitive league tables of actual progress amongst the cohort.

RESULTS The progress of the MetroGnome very clearly emerged as the expected benchmark performance of the cohort, with most students calibrating their efforts to either keep up with or not fall too far behind the performance benchmark. There are issues with the intended perception of minimum performance vs the emergent perception of adequate performance that need to be resolved; however overall progress is much better for the MetroGnome supported cohort than the cohort without out. An unanticipated consequence was the significant ill feeling toward the MetroGnome on the part of the student cohort.

CONCLUSIONS Making progress benchmarks explicit has served to improve progress through the cohort; however the anthropomorphication of the benchmark into the form of a Garden Gnome has led to some unanticipated side effects that will need to be adapted for in future implementations.

Introduction

A key feature of the engineering course is self-directed and self-motivated learning (Knowles, 1975; Butler & Cartier, 2005). In order to complete the multi-session subject ENG271, student engineers must successfully complete at least 240 topics from the Topic Tree. The topics are presented to the students in a recommended order, but there are few fixed prerequisites – students can jump ahead and skip topics if they wish, but they must still accumulate a total of 240 earned topics (Sevilla & Morgan, 2016).

The students have three semesters in which to accumulate these topics. In addition they also have access to the materials over the non-semester break periods. Therefore in total they have around 64 weeks from the commencement of the subject to the deadline for completion; of these, around 36 are explicit teaching weeks.

The pacing is therefore very simple. Students who wish to only complete topics during semesters will need to complete around 6 per week; students who wish to complete topics continuously over the holidays need to complete around 4 per week. This pacing is made clear to all students at the commencement of their studies, and while intellectually this may be clear to them, their behaviours show that they have not internalised this expectation.

Slow early progression leads to a significant risk of non-completion by the end of the subject. The latter two categories introduced a substantial risk for the management of the program. At the completion of the first three semesters, all CSU student engineers move in to industry as Cadet Engineers. To be eligible for placement as a cadet, a student must successfully complete ENG271; however the process of allocating cadets to hosts has to be finalised three weeks before the results of ENG271 can be known. As a result, we are required to predict in advance whether a student is going to complete ENG271 successfully, and then manage this element of the placement process – balancing the risk of not placing a student who then successfully reaches the target against the risk of having to “un-place” a student who does not complete.

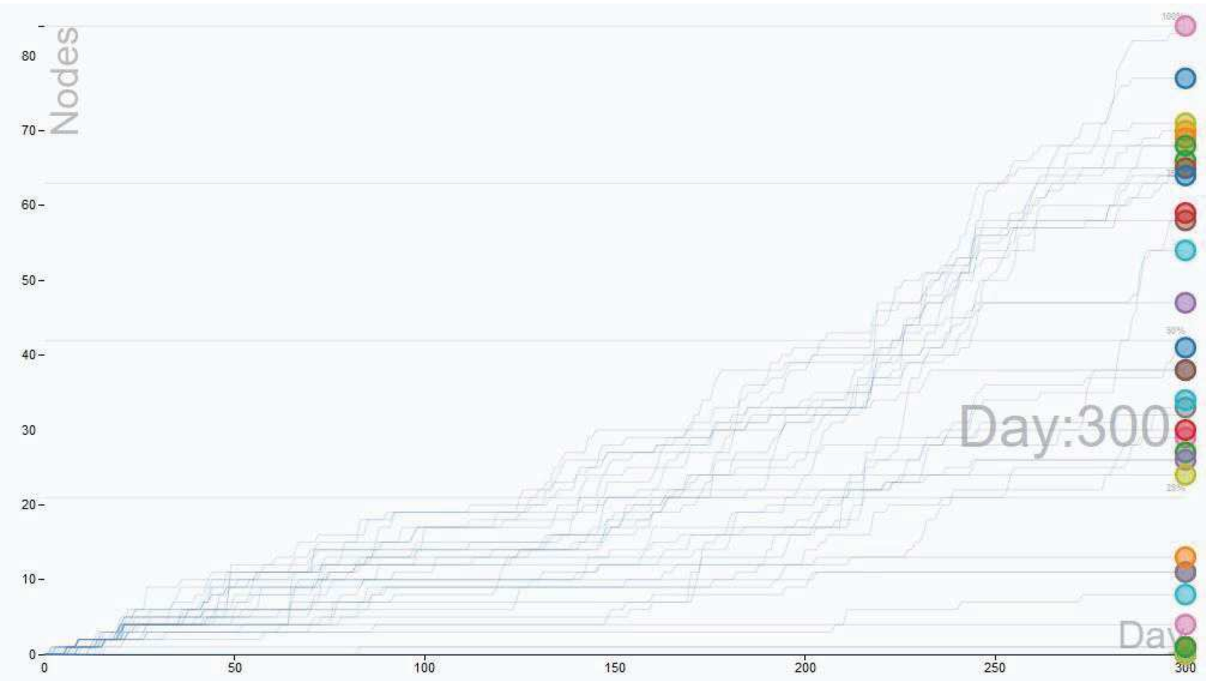

Figure 1: The first 300 days of Cohort 1.

Nodes in Figure 1 represent topics on the tree. Inspection of Figure 1 will reveal that all members of the cohort are short of the 80 to 120 topics *needed by week 20* (assuming need is defined as the 4 to 6 topics per week described above). As such, some kind of intervention was necessary to encourage earlier engagement with the 240-topic assessment item (even though it is not assessed until nearly 18 months after the start of the first session). The academic team discussed interventions such as posting a leader board (rejected because of the demoralising effect on the slowest members of the cohort); the Yellow line in the pool (although there was not a consensus for a 4 topic per week or 6 topic per week or world record movement of the line…); etc. A key concern was providing the appropriate scaffolding to allow them to work in a self-directed environment (Sevilla & Morgan, 2016). Eventually, a metronome was chosen to set the pace, and it was agreed that the metronome be set to the slowest *likely to success in going on placement* pace.

What's a MetroGnome?

It was clear from the behaviour of our first cohort that there was no immediate consequence for slow topic acquisition. There was an intellectual understanding that this mean that more work was being deferred and accumulating for their future selves; but there was no immediate now consequence for them to face. It was important to develop that immediate consequence without removing the self-directedness of their study. A coercive assessment target of weekly topic completion would absolutely have provided the motivation required; however that motivation would have been entirely extrinsic (Schunk, Meece & Pintrich, 2014), and would not have developed students' ability to plan and monitor their own work.

The solution that was chosen was gamification (Huang & Soman, 2013; Kapp, 2012). Rather than a coercive requirement, building a cultural expectation through a less threatening competition was chosen as the way forwards. Competition can be a strong motivator – if it is a competition you can win (Moore, 2014). We deliberately wanted to avoid establishing a situation where student engineers felt that they had fallen massively behind the leaders and would never be able to catch up. The fastest progressing students do not need more motivation (Ryan & Deci, 2017); we needed a mechanism to help the backmarker move forwards.

There is a range of learning styles amongst any cohort, and their response to deadlines varies. Three archetypes were identified within the cohort: Turtles, who plod along at a constant pace each week and reach the goal steadily and inevitably; Frogs, who make a series of small hops to get to target; and Kangaroos, which make infrequent large hops to reach the target. The individual progress for each student engineer in cohort 1 is depicted in Figure 1. All behaviours are clearly evident amongst members of cohort 1. Some student engineers stay true to form throughout, whilst others exhibit all three behaviours at time during their first 300 days. And some roos are still waiting for their first big jump even 300 days into the session.

Turtles vs frogs vs kangaroos

From a risk management perspective, it is the turtles that provide the lowest risk. Students who are progressing in a steady, consistent manner are the most predictable; combining a strong history of good weekly progress with the progress already made are the lowest risk, as they are the least likely to suddenly not reach the goal. From this perspective the ideal student would be one who proceeds every week in a lockstep cadence – essentially ticking away like a metronome. This musical metaphor was a potential option that was explored, due to the large number of students in the cohort for whom music is an identified hobby or interest.

The origins of how a metronome became “the MetroGnome” idea are lost in the mists of time; however the choice to anthropomorphise our cadence comes with significant advantages. Making the MetroGnome a person (see figure 2.) allowed us to provide variability, personality and agency to the cadence that we wished to set.

Figure 2: The MetroGnome, a proud member of the Bravo cohort.

In reality, no student is ever going to maintain an exact cadence for sixty-five consecutive weeks; and establishing an expectation that this is possible, or even healthy, is counterproductive. By humanising the cadence, we give the option of varying the number of topics expected each week. Certainly the clear average is sufficiently large so as to ensure adequate progress overall; but the MetroGnome has good and bad weeks, the same as the students do. This allows us to show that variability of performance is acceptable, provided it is managed. It also allows us to show that we are aware of the competing demands upon the cohort’s time by having the MetroGnome slow down in a week when we are aware that all of our students would also be slow – examples of impedance include: residential games, state of origin, grand finals, mid-session and summer break get away with mates from back home, etc. It is not important that progress during a particular week is slow, even slower than the MetroGnome. What is important is that increasing the average topics per week during some other period of time compensates for slow weeks.

The MetroGnome has personality in a way that a ticking clock does not. We are able to ascribe emotions and desires to him; he is able to be a part of the cohort, rather than simply an appliance. The original intention was that he become somewhat of a mascot for the cohort, and thereby a potential avenue for introducing cultural messages into the student body. As a “person” the MetroGnome has agency. While not self-mobile, he can be moved around the Engineering building. He can attend meetings and events; he has a tangible presence within the building, rather than being just a number in a weekly email.

Paper topics Patterns of Topic Acquisition – before & AFTER

The topic progress of the cohort 1 and cohort 2 are depicted in Figures 3 and 4 respectively. Both cohorts began university studies at the end of February, so the figures depict their topic progression over the first 6 weeks (approximately one month of session, plus the first mid-session break). Whilst not all attributable to the MetroGnome, you will see in the figures, both the number of topics being attempted, and the number of student engineers attempting these topics has significantly increased between cohorts 1 and 2.

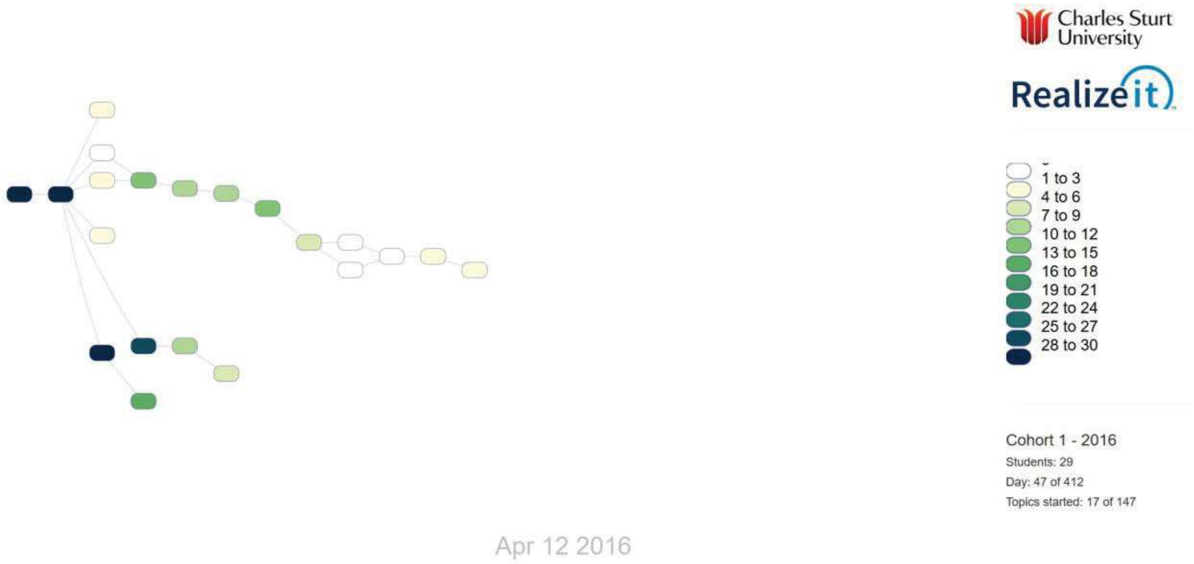

Figure 3: Topic progress on the first April 12th for cohort 1.

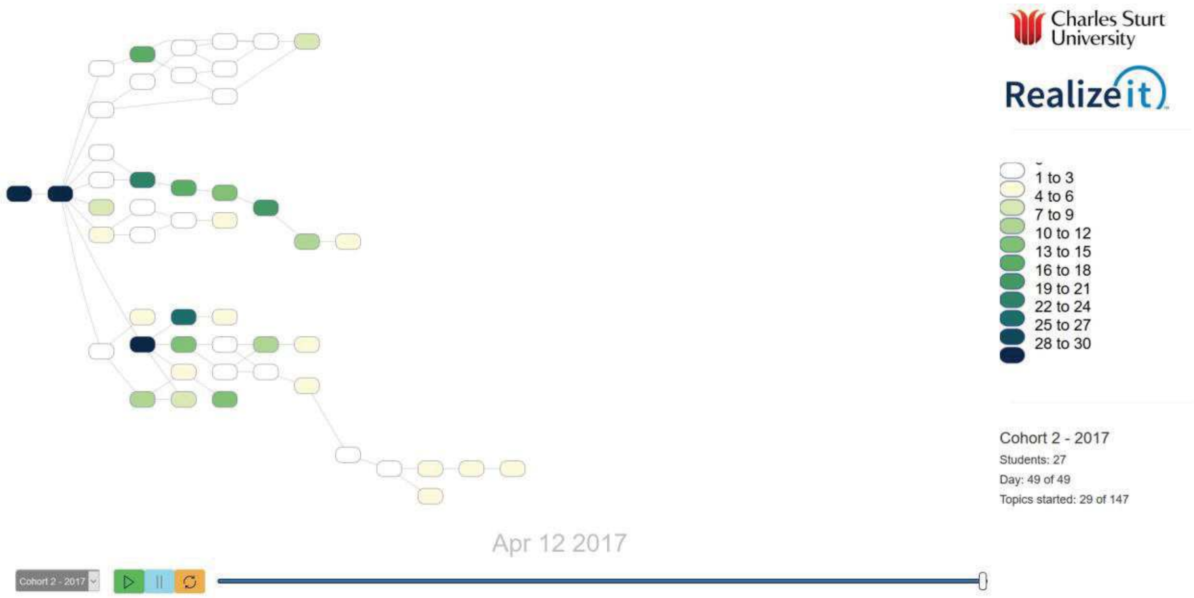

Figure 4: Topic progress on the first April 12th for cohort 2.

Anecdotal observations

The progress of the MetroGnome was intended as a clear signal as to the minimum acceptable progress level for the cohort; that any student who was not keeping up with the MetroGnome was at risk for non-completion, and thus could be targeted for intervention and support. This was not how his progress was perceived. Rather than being a minimum threshold, his progress was normalised as the acceptable or expected performance – the yellow line (target) in the pool, rather than the back of the peloton (as intended by the academic team).

The presence of the MetroGnome made the progress issue visible where it had previously been silent; however the conversations were largely missing the point. All students understand that they need to be "ahead of the MetroGnome"; but rather than embracing this and progressing, we found them haggling over whether the official count was correct, and obsessing on it being unfair that topics submitted but not yet marked couldn't be counted towards being ahead of the MetroGnome.

A significant number of our students struggle to keep up with the MetroGnome; there is the possibility that constant reminders of this are serving to demotivate rather than to encourage (Pajares, 1996). While at a certain point students need a realistic self-appraisal of their progress, we must not discourage them from learning. What is clear is that the MetroGnome is deeply unpopular amongst a subset of the cohort. He has been found placed in a corner facing the wall; he has not become the cherished mascot that we had hoped he would be. In short, the student engineers began to dislike the MetroGnome, exclude him from meetings, etc. In other words, he absorbs much of the blame and anger formerly reserved for the course director…

One incidental side effect of the introduction of the MetroGnome was a decrease in emphasis on the project based learning (PBL) portion of the curriculum, i.e., the engineering challenges, that ran in a parallel subject. By strongly emphasising each week to students the importance of topics, and by updating them with their progress and comparing that to the MetroGnome, the teaching team sent a clear signal as to what was valued. The flip side to this signal was that the other parts of the curriculum, which were not the subjects of weekly updates and sans MetroGnome, must therefore have been less important. This led to a decreased emphasis on, and performance in, the Engineering Challenge subjects. Whilst emphasizing the importance of what had been neglected by the first cohort, the MetroGnome also deemphasized the importance of what had been the most visible success of the CSU Engineering program.

Conclusions

Making progress benchmarks explicit has served to improve progress through the cohort; however the anthropomorphication of the benchmark into the form of a Garden Gnome has led to some unanticipated side effects that will need to be accounted for, and adapted for in future implementations. Achieving the perfect balance between emphasis on topics and performance in the PBL subjects is an ongoing challenge. The MetroGnome as a member of cohort 2 has achieved the desired effect, and it is likely that a new MetroGnome will join each future cohort. That said, the CSU Engineering teaching team will continue to explore brave new ways of dealing with the unintended consequences – most notably restoring the balance between projects and topics. Both are cornerstones of the CSU Engineering model (Morgan & Lindsay, 2015)

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Creativity in Mechanical Design: Exploring Suitable Methodologies for Better Practice

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C5: Systems perspectives on engineering education

CONTEXT

The Unit of Study, Mechanical Design 1 is a traditional mechanical engineering design subject that depends on the use of lectures and texts focusing on applied solid mechanics content in key design areas but historically less so on creativity, creative methods and the design process. The methods used to generate innovative ideas with a mechanical focus are seldom described in the standard mechanical design literature. When students are given set tasks, they are able to readily complete mechanical design problems to varying degrees of completion when presented with an initial creative design framework. However, when the creative design framework is removed from the problem, an impediment that is most likely caused by a lack of developed creative design skills has been observed.

PURPOSE

The use of idea generation methods that have not traditionally been used in mechanical engineering design based literature are explored with a future aim to improve student's skills in developing innovative creative solutions that are suitable for subsequent survey analysis.

APPROACH

The initial approach decided upon before a comprehensive study takes place, emphasised creativity and creativity methods within a milestone lecture and reinforced its importance in subsequent mechanical design focused lectures and tutorials. Informal discussion and observations made during tutorial sessions reinforced the viability of future work.

RESULTS

Positive feedback in discussions held indicated that when more emphasis was placed (by way of lectures, tutorials and discussions) on the use of a creativity method, a more productive outcome in ideation (idea generation) was noted. It is expected that the use of broader and more socially open idea generation methods such as Design Thinking will yield more and better mechanical design ideas than the sole use of the traditional linear design process.

CONCLUSIONS

This discussion paper has found that placing greater emphasis on creativity in a mechanical design framework is more successful than those used in the traditional mechanical design process. A more formal study will commence and be undertaken across the next twelve months by way of a formal survey and qualitative data analysis. The use of richer content more focused on creativity will be included into mechanical design units of study with an outcome giving graduates greater idea generation skills that are readily transferable into industry or potential postgraduate study needs.

Introduction

Creativity in the context of engineering courses is typically defined by authors such as Daly et al (2014) as, ‘The ability to engage in a creative process’. Whilst Howard et al (2007) refer to a creative process rather than creativity and define it as, ‘A cognitive process culminating in the generation of an idea’. Widely used mechanical design based teaching texts such as Shigley et al (2004) and Norton (2006) do not directly refer to creativity, but the ‘Design Process. Shigley et al defines the ‘design process’ as an ‘innovative and highly iterative process’ and emphasises that it is a ‘decision-making process’. Similarly, Norton (2006) states that the design process is, ‘essentially an exercise in applied creativity’.

In summary, the definition of creativity varies if and when it is noted in the literature. The absence, apparent lack of emphasis and unity in the definition of creativity is a major concern as the important role that creativity plays in engineering solutions cannot be underestimated. The need for creativity in a design based curriculum is critical. Christiaans and Venselaar (2005) (cited in Charyton 2015) state, ‘65 percent of engineers in the workforce (from mechanical, application and manufacturing engineering companies) agreed that today’s engineers need to be more creative and innovative to be globally competitive’. Creative solutions are clearly valued and needed by society.

There should thus be pressure on Universities to put greater emphasis on ensuring that creativity is a part of design courses offered in their engineering programs. Stoufer et al (2004) cited in Charyton (2015) further emphasises this point, ‘Without training in the fundamentals of creativity, only 3 % of the population associate creativity with engineering’.

Background

The key goals of this paper are to present the current state of creativity in the mechanical design Unit of Study (UoS), Mechanical Design 1, MECH2400/9400 offered at the School of Aerospace, Mechanical and Mechatronic Engineering, University of Sydney and the future potential for development within the mechanical stream. The MECH2400 cohort is made up of undergraduate students undertaking a core UoS that is a part of the Mechanical, Aeronautical, Biomedical and Mechatronic second year streams; whilst the MECH9400 cohort is made up out of postgraduate students who mostly originate from overseas universities.

In 2017, the total number of students enrolled in the UoS equalled 330. The current large number of students has created challenges in terms of repour between the lecturer and students. This is a particularly salient point in a design based UoS as students are less likely to engage in discussion or raise questions within a large cohort. Coupled to this point, very few of the students have any previous practical mechanical design experience.

This UoS also serves as a platform for further study in more stream specific UoS offered by the School. Within the mechanical stream, Figure 1.0 illustrates the UoS as a key foundation stone within the framework of a proposed Engineering Design Major and subsequent core UoS that focus on Manufacturing Engineering.

Within the mechanical stream the UoS delivers introductory content that is broadly divided into three core components;

1. Graphics - Freehand sketching, engineering drawings using AS1100 as a framework and CAD using SolidWorks^{TM} as a medium.
2. Design - Creativity, the design process and stress/strain analysis of machine elements and bearings using derived equations.
3. Power Transmission - Analysis of common machine elements involved in power transmission throughout a mechanical system.

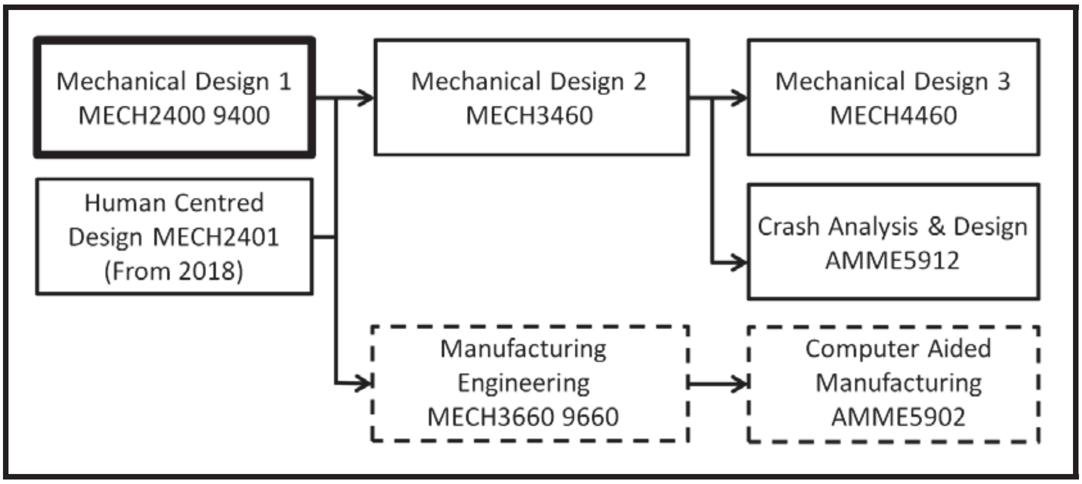

Figure 1.0 Proposed Engineering Design Major UoS Map (Source: Briozzo, P. 2017)

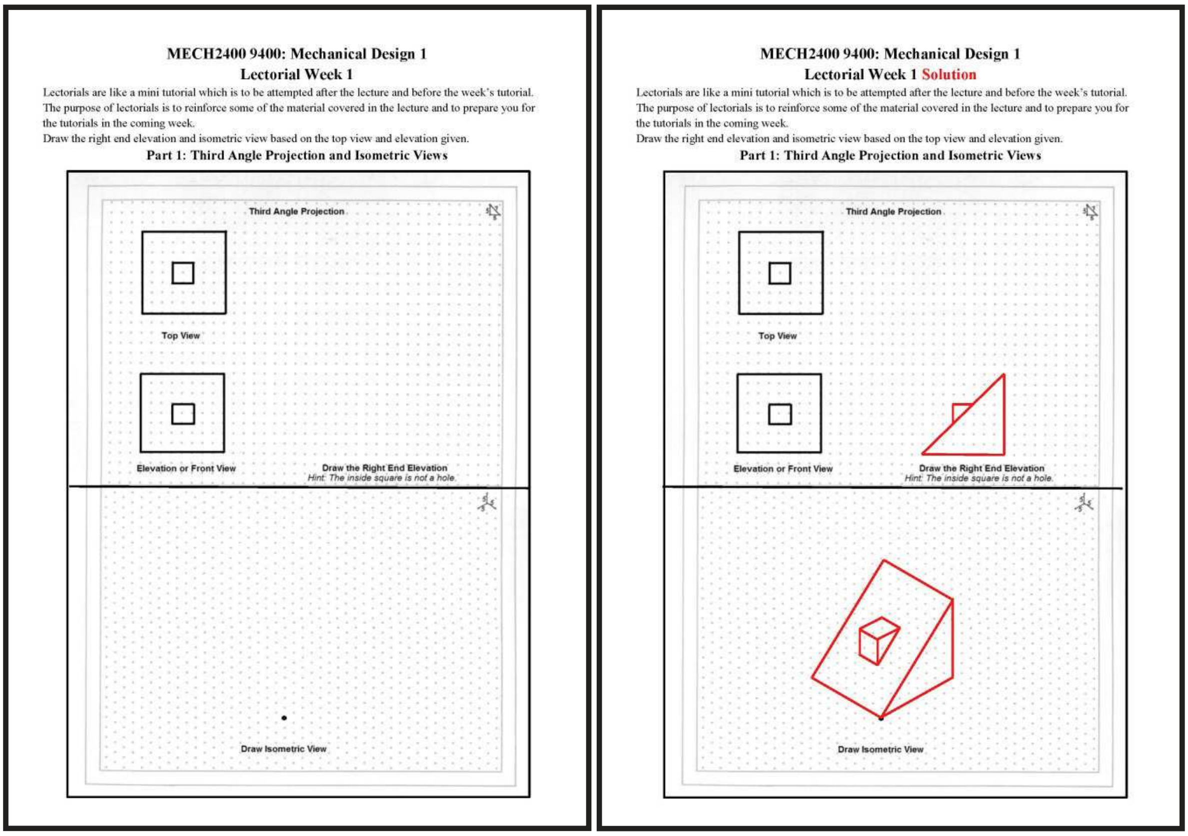

Figure 2.0 and 2.1 Lectorial and Solution (Source: Briozzo, P. 2017)

Lectures

Lectures are given in a traditional format twice weekly for a period of one hour each in duration. As at 2017, the number of students easily exceeds 300. However, a recent trend noted by the author is that the number of students attending the lectures has dropped. The typical flow of the lecture is for the author to pause midway and introduce a “lectorial”. A lectorial is a mini tutorial to be undertaken during five to ten minutes of the lecture. Informal discussions with students have indicated that lectorials promote a positive and active learning environment rather than a passive listening space. It has been informally observed by the author that students that take part in the regular lectorials often demonstrate engagement with the topic at hand and are better placed to undertake the week's tutorials. Figures 2.0 and 2.1 demonstrate a week 1 lectorial and its accompanying solution that reinforce recent delivered lecture material, focusing on special concepts, third-angle and isometric projections.

Tutorials

Tutorial enrolments are large and range from 60 to 100 students per room. Students are generally given printed tutorial material related to the lecture content of the week. Tutorial content is also available online but it has been observed by the author that printing a separate sheet focuses the task at hand. Once tutorials have been undertaken, the students attempt is inserted into a Portfolio that is self-assessed and reviewed by tutors on a monthly basis. The tutorials also provide a meeting place for group assignments and informal meetings with the author.

Course syllabus and weekly content

A breakdown of the weekly content and the assessment schedule is provided in Table 1.0.

Table 1.0 Simplified Unit of Study and Assessment Outline (Source: Briozzo, P. 2017)

Week	Weekly Content	Assessment
1	Freehand Sketching; Orthogonal Projections + CAD	
2	Detail & Assembly Drawings to AS1100 + CAD Design for Reliability; (Guest Lecturer)	
3	Tolerancing - Dimensional & Geometric + CAD	Free Hand Sketch (5%)
4	Specifications & Drawing Analysis + CAD	
5	Design & Creativity; Applied Stress (Beams) + CAD	Design Portfolio 1 (5%)
6	Design of Structural Bolted Connections to AS4100 + CAD	Group Assignment: Design, Analysis & Eng. Drawings (10%)
7	Bearings Plain & Rolling Element + CAD	Quiz 1 (20%)
8	Springs + CAD	
9	Geometry of Gears +CAD	Design Portfolio 2 (5%)
10	Design of Shafts to AS1403 + CAD	Group Assignment: Design & Build (20%)
11	Keys and Shrink Fits & Couplings + CAD	
12	Flat & V Belt Drives + CAD	Design Portfolio 3 (5%)
13	Toothed Belt Drives & Engineering Analysis + CAD	Quiz 2 (20%); Group Assignment: Gearbox Design (10%)

Initial graphics content

The UoS begins by introducing students to basic freehand drawing skills, in order to generate pictorial projections incorporating straight lines and ellipses. The pedagogy used is a combination of; traditional lectures using a lectern based visualiser, lectorials and a conventional tutorial based task associated with each lecture topic. Orthogonal projections and the remaining content related to student learning in graphics are covered in the same format.

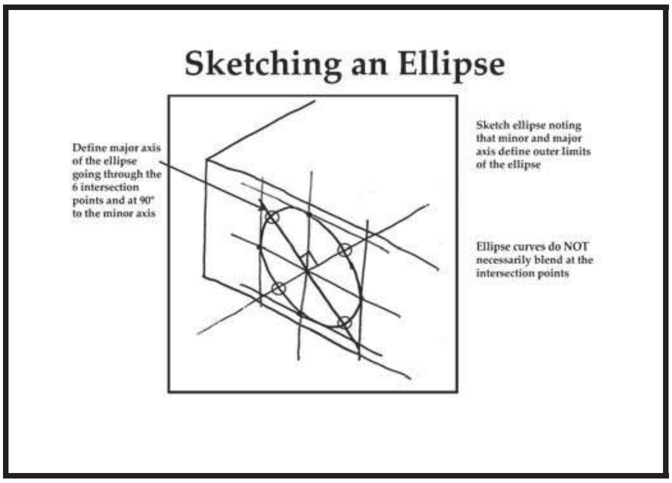

Figure 3.0 Sketching an Ellipse (Source: McHugh, P. 1993)

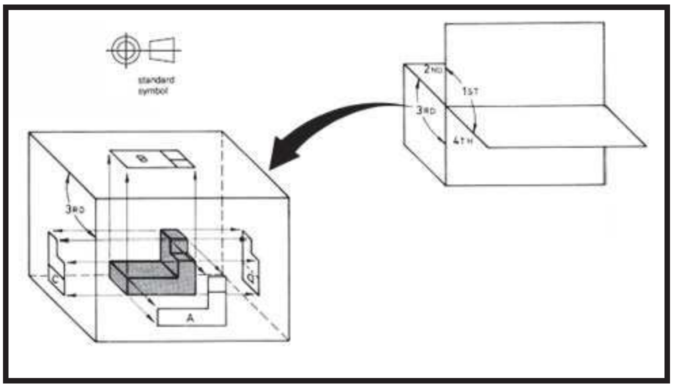

Figure 3.1 Third Angle Projection (Source: Boundy, A. 2002)

The importance of freehand sketching skills in creativity and the design process is paramount. Goldschmidt and Smolkov (2006) (cited in Charyton 2015) state, ‘Sketching is instrumental in design problem solving and results in creative solutions.’ Blackler (1995) goes further to reinforce engineering drawings as a necessary topic in design, ‘Engineering drawings are an essential element in the design process itself, in communicating the design outcome and in preserving the design details for future reference’. Effective sketching skills and the ability to generate and read engineering drawings are highly valuable life-long skills required by all engineering graduates within their respective discipline. These are skills that are technology independent. It is the author’s experience that skills gained in the use of specific CAD packages quickly become obsolete as software and hardware revisions are introduced across a relatively short period of time.

Creativity in mechanical design

In this UoS, creativity in mechanical design is delivered following the content on graphics. The topic of creativity in mechanical design is broken down into six main methods that students may wish to consider using to generate ideas:

1. Trial and Error: Trial and error is presented with Edison as its leading proponent. However, this creativity method is not encouraged in the UoS as it lacks a hypothesis and does not require valuable research to be undertaken, which may have averted time consuming false leads. Whilst the method may produce a random solution (without a benchmark) it may be applied in cases that lack any background knowledge. Trial and error as a creativity method is observed to be very common amongst students initially faced with their first “design and build” or “competition” based tasks.

2. Brainstorming (in a Group Setting): Group brainstorming is promoted as a divergent creativity method in the UoS as most of the assignments require group work, regular meetings and ongoing positive repour between students. This creativity method is also directly supported in the tutorials by encouraging “round table” discussions with direct support from tutors and the UoS coordinator. Assignment assessment in the UoS is indirectly linked to successful group work which depends on the generation of a number of creative solutions. The use of trade-off tables as demonstrated in Table 2.0 are encouraged as an effective divergent method that allows for the comparison and evaluation of a number of brainstormed solutions. It should be noted that Trade-off tables are not a creativity method but a tool used to categorise brainstormed ideas.

Table 2.0 Example of Trade off Table (Source: McHugh, P. 1993)

Concepts		**Beam & Rod**			**Swing Link**			**Rack & Pinion**	
Functions	**Value**	**Score**	**V*S**		**Score**	**V*S**		**Score**	**V*S**
	(/10)	**(/10)**	**(/10)**		**(/10)**	**(/10)**		**(/10)**	**(/10)**
Smooth Finish	2	6	12		4	8		9	18
Corrosion Resistance	6	4	24		3	18		2	12
Speed	4	5	20		3	12		6	24
Stability	8	4	32		9	72		7	56
Range	4	7	28		4	16		5	20
Total			**116**			**126**			**130**

3. Analogy: The use of analogy as a creativity method is highly encouraged as it draws on previously well-known and successful designs and encourages their application in an alternate environment. Analogy inspired designs may also be drawn from nature. Figures 4.0 and 4.1 illustrate a successful implementation of analogy as a creativity tool. Students readily accept and use analogy in their group assignments as it is easy use and completed by readily available internet search engines.

Figure 4.0

Weddell Seal showing off her flippers!

(Source: Costa, D. 2017)

Figure 4.1

Flippers

(Source: Unknown. 2017)

4. Inversion: Inversion is defined by Clear (2017) as, ‘This way of thinking, in which you consider the opposite of what you want, is known as inversion’. The creativity method

inversion is presented but not readily implemented by students as it requires a more structured definition of examples than the tutorial time allows. A simple case is provided, ‘How to do you clean windows so more light can get in? Reconsider the situation as one of letting more light in, not necessarily cleaning the windows.’

5. Design Thinking: Design Thinking (DT) or human-centred design focuses on the client needs rather than technical problems. Figure 5.0 breaks down the various steps in the DT process. One of the leading proponents of Design Thinking, Brown (2008) defines DT, “a discipline that uses the designer’s sensibility and methods to match people’s need with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity.” DT as a creativity method, is particularly strong in multi diciplinary projects such as Project Everest, Figure 5.1. During the UoS given in 2017, students were able to directly relate to DT as a creativity method as one of the student’s from the cohort, J. Bergman (personal communication, August 24, 2017) presented their work using DT on Project Everest in Cambodia.

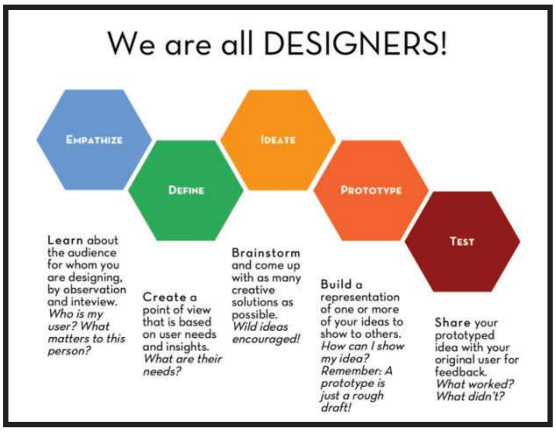

Figure 5.0

Design Thinking Process

(Source: IDEO 2017)

Figure 5.1

Project Everest

(Source: Bergman, J. 2017)

6. Mind maps: The use of mind maps as a creativity tool in the UoS is highly encouraged with informal student feedback indicating that their use is a positive move towards idea generation. Mind maps allow a broader picture of a design to be formed Figure 6.0 highlights the combined use of DT and Mind maps. Elmansy (2017) states that, ‘Mind mapping is one of the efficient methods that organise all of these (design thinking methods) in a formation and in a visually brain-friendly method.’ In contrast, Figure 6.1 illustrates a flow chart from typical mechanical design text. Note that it does not directly emphasise the creativity component of the design process.

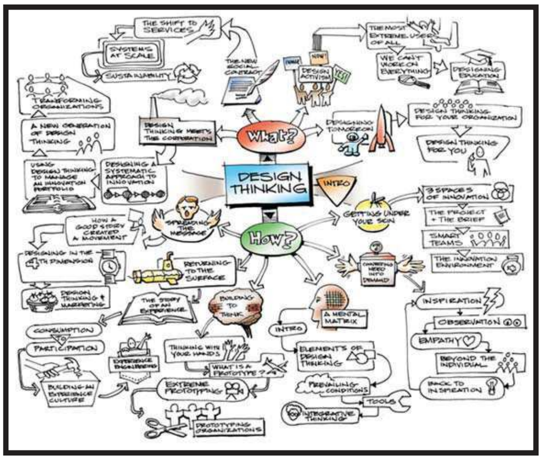

Figure 6.0

DT Mind Map

(Source: Brown, T. 2008)

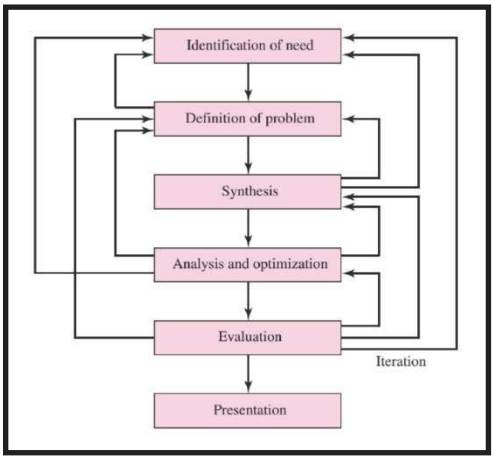

Figure 6.1

Phases in Design

(Source: Shigley et. al. 2004)

Figures 7.0 to 7.2 graphically illustrate the key steps in developing a relevant mind map within the UOS. Using a central theme of the redesign of a connecting rod that was originally designed for an agricultural purpose into a connecting rod that is needed for a racing engine, students are asked to explore the features of the connecting rod that need to be researched and redesigned. Students are initially asked to draw two faint lines diagonally opposed to accurately locate the centre of the page. Figure 7.1 illustrates a basic freehand line sketch that graphically identifies some of the key features of the connecting rod is drawn to define a central starting point. The line drawing is then converted into a coloured shaded image (in this case, grey) as shown in Figure 7.1 in order to give the image a level of realism. It is important to actually sketch the image by hand rather than to use an already prepared image in order for the participant to gain a level of geometric familiarisation.

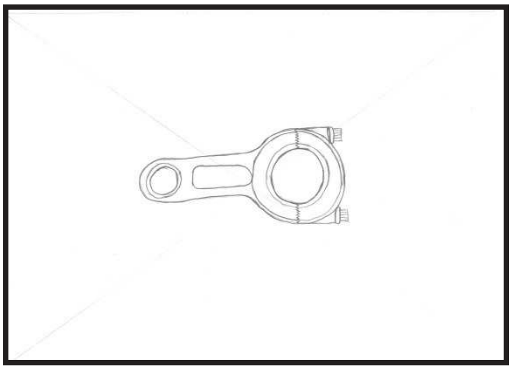

Figure 7.0

Connecting Rod Initial Line Sketch

(Source: Briozzo, P. 2017)

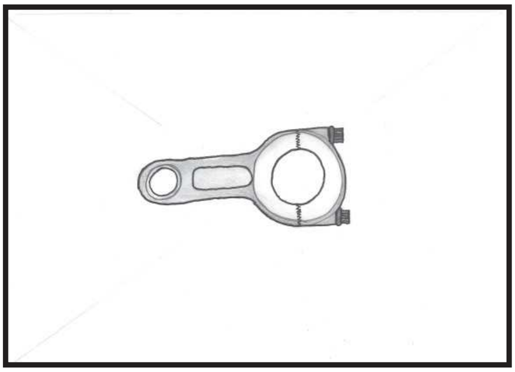

Figure 7.1

Connecting Rod Shaded Image

(Source: Briozzo, P. 2017)

In order to give the image a level of realism, it is important to actually sketch the image by hand rather than to use an already prepared image in order to gain a level of geometric familiarisation with the design at hand.

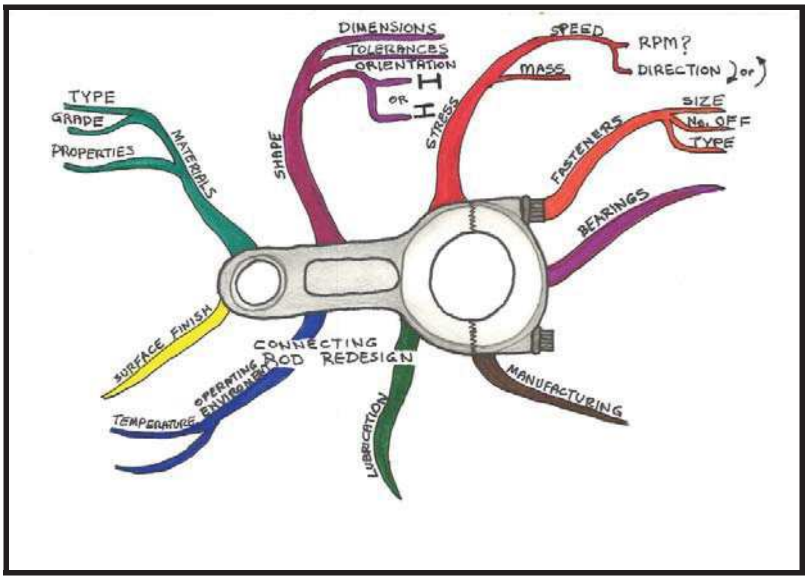

Figure 7.2 Connecting Rod Mind Map (Source: Briozzo, P. 2017)

Once a level of guidance through some of the features that need redesigning has taken place, students are guided by tutors to research key points such as; boundary conditions, materials, manufacturing, shape & dimension. These are core points that are represented by coloured thick branches that radiate outward from the central theme, gradually thinning and diverging outward to represent the various sub themes associated with the redesign. Figure 7.2 defines most of the features of a basic Mind map as applied to a mechanical design based problem.

Pahl et al (2007) refer to semantic networks as a graphical method of representing a mechanical design based problem. However, semantic networks differ from mind maps in that they emphasise the connections that exist between the separate features rather than the progressive idea development that radiates from a central point. Figure 8.0 illustrates semantic network for a bearing.

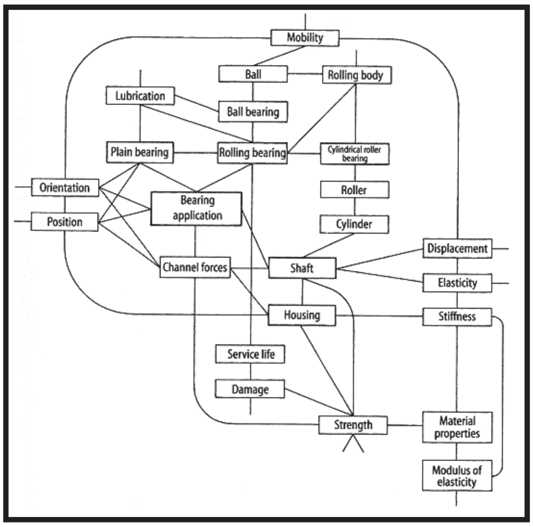

Figure 8.0 Extract of a Semantic Network Related to Bearings (Source: Pahl, et al. 2007)

Results

Tutors observed some students' attempts at applying the mind map method resembled closely to a semantic network, similar to Figure 8.0, consisting mostly of words or phrases within interconnected nodes, with no incorporation of sketches. Students who followed the steps introduced for constructing the mind map, included many common features as shown in Figure 7.2. Some mind map attempts included a basic outline sketch without further attempts at adding realism. Most students needed further clarification before attempting to construct the mind map, perhaps indicating their unfamiliarity with this type of activity in the UoS. Informal discussions with students indicated that using mind maps as a creativity tool assisted in the visualisation of the problem given but to a lesser degree in generating ideas.

Discussion

The informal discussions and the authors' observations of student's preferred ideation methods in mechanical design based assignments over a number of semesters warrants further research. A formal study that incorporates;

- Qualitative data gathered using ethnographic research methods to directly interview students with an aim to gather their opinions on the effectiveness of different relevant creativity methods, and;
- Graphic data gathered from mind maps and compared using criteria such as; shape, colour, depth of text content, variety, quantity etc.;

Image analysis methods incorporating coding techniques such as those suggested by Cohen et al. (as cited in Rose 2007) that carefully dissect each facet of an image by asking a systematic series of questions e.g. "What are the features of the image", may be readily applied to any samples of drafted creativity samples collected.

It is proposed that creativity methods could be introduced to other components within the course syllabus, with the aim to foster students' confidence in implementing more creativity tools in mechanical design problem solving.

Conclusion

This paper has presented the current status and need for the development of creativity skills in students in a UoS that focuses on the area of mechanical design. However, creativity and innovation skills should be life-long skills that are instilled in graduates in each UoS that they undertake in their degree. The authors feel that a necessary start must be made in order to establish; what are the initial skills in creativity that students possess, which creative methods are relevant to a particular UoS and which are the most effective for a given problem as a matter of priority.

Acknowledgements

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A New Project Management Regime

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SESSION: C1: Integration of theory and practice in the learning and teaching process

CONTEXT Throughout 2015 and 2016, the Faculty of Engineering and the Built Environment at the University of Newcastle re-envisaged the suite of engineering programs on offer to meet the future needs of students and society. One of the key areas addressed in the changes was the formation of a strong backbone of professional practice courses running vertically through the programs. One of these professional practice courses was a complete revision of the dedicated Project Management course. This paper describes the transformation we have commenced, the pitfalls and successes.

PURPOSE The purpose the new course (ENGG3500: Managing Engineering Projects) was not to make our students "Project Managers" *per se*, but rather, to give all of the Faculty's 230 engineering students a clear understanding of the broader philosophy and expectations that underpin the project-based reality of almost all engineering-related workplaces.

APPROACH The course centred on the themes presented within the Project Management Body of Knowledge (PMBOK). The students worked in flipped-mode, with pre-reading material and presentations made available. The first part of a weekly "lecture" summarised key elements of that week's Project Management (PM) theme, which was followed by a senior-industry person giving a presentation that highlighted their own PM experiences, highlights and pitfalls. Tutorial sessions provided opportunities for the students to explore elements of that week's theme, with assessment items conducted within tutorial; additionally, current practitioners facilitated all tutorial sessions. Students had to work in project-teams throughout the semester, and deliver assessment items based on a project of their own choice. Their Major assessment item was a full Project Management Plan (PMP) that required multiple presentations, as well as a formal document. At the end of the course, an industry-panel of current PM practitioners received PMP presentations from 4 student-teams.

RESULTS The students assimilated PM information prior to each week's "lecture", which helped them fully appreciate the PM "life-lessons", as given within that week's Case-Study. Indeed, this engagement with Senior PM's was a great success, with both industry and students feeling that the transfer of information, and, mentoring, was one of the highlights of the course. Students were able to see and appreciate the benefit of each week's Case-Study. All Case-Study presentations were Pro-bono. Industry engagement (within tutorial sessions) was, again, extremely well received by the students, as any tutorial/assessment questions were answered, on the spot, by people currently working as PMs. Future course-development will focus on "sharpening" the assessment items, with a view to achieve the same outcomes but with less assessment items. Other development will improve how student's peer-assess each other for their work within their own PM-team environment.

CONCLUSIONS The students received a clear understanding of the (broad) processes, philosophies and language of the current Australian and international PM workplace. Finally, the weekly Case-Studies by senior industry PM practitioners was extremely well received by the students, as it gave them an immediate and tangible perspective on the reality of PM requirements, and across all facets of leading and managing engineering projects (as defined within the PMBOK).

KEYWORDS Engineering project management, industrial engagement

Introduction

Throughout 2015 and 2016, the Faculty of Engineering and the Built Environment at The University of Newcastle re-envisaged the suite of engineering programs on offer to meet the future needs of students and society. One of the key areas addressed in the changes was the formation of a strong backbone of professional practice courses running vertically through the programs. One of these professional practice courses was a completely new implementation for a dedicated Project Management (PM) course. This paper describes the development and first deployment of this new course, highlighting the pitfalls, successes and lessons learnt.

The purpose the new course (ENGG3500) was not to make our students "Project Managers" *per se*, but rather, to give all of the Faculty's engineering students – enrolled across 28 different programs – a clear understanding of the broader philosophy, language and expectations that underpin the project-based reality of almost all engineering-related workplaces. The new course fits in different places within various programs, some students are in their 3rd year, whilst some in their 4th year. In either case, all of the students have an opportunity to use the PM skills learnt in the remaining semester(s) of their program.

Approach

The course centred on the 12 related themes as-presented within the Project Management Body of Knowledge (PMBOK, 2013):

- Organizational Influences and Project Life Cycle
- Project Management Processes
- Project Integration Management
- Project Scope Management
- Project Time Management
- Project Cost Management
- Project Quality Management
- Project Human Resource management
- Project Communications Management
- Project Risk Management
- Project Procurement Management, and
- Project Stakeholder Management

Indeed, one course (within just one semester) is clearly not enough time to make any undergraduate student (nor a masters-level student) a fully-fledged project manager, so that is not what was attempted. Rather, the intent was to have the students engage with the PMBOK's themes, and, ultimately, have them work individually - and in teams - in their production of a formal Project Management Plan (PMP).

The actual course content for ENGG3500, across the semester, is given within Table 1.

Table 1: Weekly course content for ENGG3500

Week 1	Introduction to course, Defining a project, Defining project management
Week 2	Project management roles, Belbin's team roles
Week 3	Initiating a project, Gaining project approval, The project charter, Project scope
Week 4	Project management methodologies and approaches, Stakeholder management
Week 5	Developing a project schedule, Software applications to develop a schedule
Week 6	Risk management, Controlling risk
Week 7	Human resource management, Communication management
Week 8	Cost management
Week 9	Project ethics
Week 10	Quality management, Procurement management – what is procurement?
Week 11	Closing the project
Week 12	Presentation of Project Management Plans to an Industry Panel. NOTE: only Four Student-Teams presented on this day, with the selection of Student-Teams based on every team's Presentation-performance during Week 11's Tutorial session.

For semester weeks 1-11 the students worked within the following regime:

Flipped coursework material. The students were given access to a variety of "pre-reading" documents, short videos and lecture slides; all provided via the University's learning management system.

- The intent was that students would come to the weekly "lecture" with a reasonable understanding of that week's PMBOK theme, with a view that they would be better situated to receive, and understand, that week's industry presented Case-study.
- It was expected that these weekly "pre-reading" packs would typically require 1-2 hours engagement. For example, prior to Week 9's Project-Ethics case-study, the students were expected to locate the following documents (working web links were given) with the expectation that they would access, download and read this information:
    - Nelson, L & Netherton, M.D. (2017) Project Ethics, *Week 9 summary notes for ENGG3500*.
    - Bazerman, MH and Tenbrunsel, AE (2011) *Ethical breakdowns.*
    - Hart, M (2011) *The ethical lessons of Deepwater*.
    - McFarland, M (2012) *Occidental Engineering Case Study*: Part 1 – An ethics case study and commentary, and Part 2 – A tutorial on ethical decision making.

Senior Industry presenters. The first part of each weeks "lecture" was a quick summary of the key elements of that week's Project Management theme – as given by the Course's Coordinator. This was immediately followed by a case-study, presented by an industry-based guest speaker.

- All of the people giving these case-studies were very experienced, senior Industry people. Their brief was to give a presentation highlighting their own (and very personal) PM experiences, highlights and pitfalls, and as they related to that week's PMBOK theme (as detailed earlier in the Approach section of this paper).
- Indeed, the University was extremely fortunate to have case studies delivered by Senior Industry people, as listed at Table 2. Further, each of these presenters were extremely gracious in giving their valuable time - and experiences - pro-bono.

Industry Tutors. Later each week, a single 2-hour tutorial session provided students the opportunity to discuss and explore elements of that week's PM theme, with some minor assessment items (listed later in this paper) conducted within the tutorial sessions.

- Each tutorial session was facilitated by industry-sourced tutors, where each tutor was a current PM practitioner. Table 3 lists the numbers of various Industry Tutors and highlights the diversity of PM practitioners who facilitated and advised the student's tutorial sessions.

Table 2: Senior Industry people who presented PM Case-Studies for ENGG3500

Week:	Weekly PM Theme:	Senior Industry Person:	Organisation:
2	PM roles	Bill Sidwell	Alstom ECS
3	Initiating a project	Andrew Vild	Project Everest
4	PM methodologies	Clint Bruin	ResTech Pty Ltd
5	PM scheduling	Tim de Grauw	APD Power Engineering
6	Risk	Peter Carson	NSW Roads and Maritime
7	HR management	Pierre Gouhier	RPC Technologies
8	Cost management	James Kennedy	Laing O'Rourke
9	Ethics	Jim Bentley	Hunter Water
10	Quality & Procurement	Tim Nancarrow	AMP Control
11	Closing the project	Gavin Lewis	BAE Systems

Table 3: Variety of PM practitioners who facilitated Tutorial Sessions for ENGG3500

Numbers of PM Practitioners:	Type of PM Organisation:
12	Private companies
4	Government agencies

Method of assessment

Throughout the semester, students worked in project-teams (of six people), and delivered assessment items based on a project of their own choice. A number of generic projects were offered to every team (as listed in Table 4); however, since the course was intended to be applicable for students across a range of degree-programs, teams were also given the flexibility to choose a project that they felt worked well within the particular skill-sets of their team. A sample of some of the alternate project chose by different project teams is also listed within Table 4. Whatever project was chosen by each team, that project then remained with them for the remainder of the course. If any team did wish to make-up a project of their own, they were assisted and guided in their selection by their tutor.

In the end, the choice of project was not that important, as it was not the actual project that mattered so much, rather, the goal was to allow students to develop and demonstrate their PM skills through the "*management*" of their chosen project - whatever that may be.

Table 4: Projects undertaken by some of the different project-teams

Generic projects available to all teams:	Design and build a community garden space
	Design and develop an on-campus work-placement software package
	Design and develop a land-regeneration management project for a local space
Specific projects developed by some teams:	A power-supply distribution network
	A community water-playground
	An integrated IT distribution network across The University of Newcastle
	A wall between USA and Mexico
	Development of a racing car

Assessments

ENGG3500 had a variety of assessment items: minor and major, as listed in Table 5. There was a mix of individual, group and peer marks available, with group-work marks capped at 50% of the total, and peer-assessed marks capped at 10% for any one assessment item; as per broader University policy. Finally, of the 6 minor assessment items worth 3.75%, only their top-4 were included in their final grade; the intent was to give students an opportunity to "*have-a-go*", and not be penalised for any early mistakes.

One of the goals for the assessment schedule was to provide a number of minor assessment items with a view to provide feedback on components of work that would, ultimately, end up within their final PMP. Teams were also given multiple opportunity to physically present to their tutor groups during the semester, with the intent of giving them regular feedback and thus improving their final, major, PMP presentation. The assessment schedule for the course is given in Table 5.

Each of the minor assessment items were items that would eventually, "plug-in" to the final PMP. Thus students had the opportunity to receive weekly feedback on (components of) their final PMP. Further, a 30% Major assessment was required half way through the semester. This major assessment was, in effect, 'Part A' of the final PMP, and again gave students the opportunity to submit work at the level required in their final PMP. The marking of the first part of the PMP, as an early assessment item, gave students another opportunity to receive early feedback on what was required for their final written PMP.

The final PMP assessment required a group-presentation component, worth 10% of the overall course mark. To allow students an opportunity to develop their team's presentation skills, a number early presentations were delivered by each team (within tutorial sessions) where minor marks and feedback were given immediately. The final lecture-session of the course involved the top four project-teams re-delivering their PMP, to the whole class plus an Industry panel. The industry panel consisted of the senior industry people who had given case-studies throughout the semester and the Industry sourced tutors. These four teams were awarded bonus marks, with the "Winning Team" (as determined by the Industry Panel) awarded further bonus marks to incentivise the activity.

The majority of marks were allocated to MAJOR assessment items. Indeed, 80% of the total marks were possible from 3 of the 10 assessment Items, with each of the minor items designed to be components of the Major assessment items, and where the students had time to integrate feedback from the Minor items into their Major items.

Table 5: Assessment items for ENGG3500

Assessment Item:	Type of assessment:	Involvement:	Weighting:
Minor Assessment 1	Individual submission	Individual Mark:	3.75 %
Minor Assessment 2	Group Submission	*Group mark:*	*3.375 %*
		Peer mark:	*0.375 %*
		TOTAL:	3.75 %
Minor Assessment 3	Group Presentation	*Group mark:*	*3.375 %*
		Peer mark:	*0.375 %*
		TOTAL:	3.75 %
Minor Assessment 4	Group Submission	*Group mark:*	*3.375 %*
		Peer mark:	*0.375 %*
		TOTAL:	3.75 %
MAJOR Assessment (Part A)	Written Submission	*Individual mark:*	*20.25 %*
		Group mark:	*6.75 %*
		Peer mark:	*3.00 %*
		TOTAL:	**30.00 %**
Minor Assessment 5	Group Submission	*Group mark:*	*3.375 %*
		Peer mark:	*0.375 %*
		TOTAL:	3.75 %
Minor Assessment 6	Group Presentation	*Group mark:*	*3.375 %*
		Peer mark:	*0.375 %*
		TOTAL:	3.75 %
Minor Assessment 7	Individual submission	Individual Mark:	5.00 %
MAJOR Assessment (Final PMP)	Group Presentation	*Group mark:*	*9.0 %*
		Peer mark:	*1.0 %*
		TOTAL:	**10.00 %**
	Written Report	*Individual mark:*	*25.25 %*
		Group mark:	*10.75 %*
		Peer mark:	*4.00 %*
		TOTAL:	**40.00 %**

Group work and Peer assessments.

One of the key outcomes of ENGG3500 was for students to come together in diverse teams and – collectively - produce their final PMP. Of course, bringing together a number of students from different programs (and at different levels within their programs) and requiring them to work collaboratively was challenging. Indeed, for many students, this was the first time they had worked with students from every program within the Faculty; this, by definition, created a challenging team-based environment – and not dissimilar to industry teams that are assembled from a number of different specialisations for a new project. To counter any perceived or actual concerns that "Group projects aren't fair" the course used the Self & Peer Assessment Resources Kit (Spark^{PLUS}) developed by Willey (2014). Spark^{PLUS} was used to facilitate feedback to each member of each team, as given by other members of that team.

Results

The change in teaching practice has impacted in these ways: the students were able to access and assimilate PM information prior to each week's "lecture", which then helped them fully understand and appreciate the PM "life-lessons", as given within that week's Case-Study presentation. Indeed, this engagement with Senior PM's was a great success, with both industry and students feeling that the transfer of information, and, effectively, mentoring by some very senior people, was one of the highlights of the course. Students were able to immediately see and appreciate the benefit of each week's Case-Study. All Case-Study presentations were Pro-bono; however, all industry-based tutors were paid for their time, either individually or via cost recovery to their firms. This aspect of industry engagement (within tutorial sessions) was, again, extremely well received by the students, as any – and all – of their tutorial/assessment questions were answered, on the spot, by people currently working as PMs.

The tangible deliverable for each student was their team's formal PMP. Direct feedback from members of the Industry Panel (who received the presentations from the final four project teams) was that the PMPs were of a very-high standard, particularly for students only learning the broad context of Project Management. Indeed, one senior industry person stated that she had to remind herself that the projects, as presented, were not real, and had been "made-up" by the students, such was the comprehensiveness of the plans delivered.

Challenges and Opportunities

Whilst the new course was viewed as a success, as with any new venture there is room for improvement, and ENGG3500 was no exception. A summary of key issues and their proposed solution(s) are:

- Getting industry people linked into the University's systems much earlier. Whilst industry people are, of course, already involved in many aspects of the Faculty's different programs, this was the first time that such a large course had 100% of tutor support drawn from industry. Ordinarily, such a large number of tutors would be drawn from post-graduate and post-doctoral groups, meaning that the majority of people would be already "on-board" when it comes to their access to the University's IT systems. However, the inevitable delays as so many external people were integrated meant that the Course-Coordinator's workload increased dramatically.
- The assessment-workload was logistically ambitious at the start of the course, particularly given the delay in system access for every industry tutor. This delay meant that (each week) hundreds of assessment items had to be individually retrieved, disseminated, and retrieved between the Course-Coordinator and each tutor. This workload-reality meant that the assessment system quickly became overloaded, and timely feedback to all students - in the first part of the course -

suffered. The students were scathing of this problem, and, quite rightly, saw it as a very bad example of project management.

- Future course-development will alter the assessment items, with a view to achieve the same outcomes but with less (minor) assessment items - this will reduce tutor and course coordination workload.
- The student peer-review system, whilst extremely valid, did not properly work. Not through any fault with the Spark^{PLUS} method, rather, though logistics challenges experienced as part of Course Coordination of a new course. The implementation of Spark^{PLUS} via a new IT system, which, when combined with the overloaded assessment feedback problem, meant that peer-reviews were, effectively, abandoned for some assessment items. Where peer-review didn't work, students were given full marks for the peer-review component of that assessment item. Future development will improve the peer-assessment methodology via improved IT system delivery.
- With such a diverse group of students drawn from so many programs, when any one student dropped the course the workload for the remaining members of their project team increased. It was not possible to simply re-balance the numbers within project teams by reallocating students to alternate tutorial sessions, due to the significant number of clashes with so many other classes. The solution is that next time the course is run, all tutorial groups will be run at the same time. This will, by definition, remove the flexibility of some students to choose a tutorial session that (possibly) best suits their personal time choices; however we believe it will be better to have a layout whereby students can be readily transferred between teams, and thus re-balance the numbers within each project team, such that workload is similar – and fairer – across all students.
    - The ability to run all tutorials for ENGG3500at the same time was facilitated by the serendipitous 100% redevelopment and implementation of a new timetable across the whole of the Faculty for 2018. This meant that ENGG3500, with its diverse number of programs, could be timetabled first, rather than attempting to "fit it within the gaps" of an existing timetable.

Conclusions

A completely new PM course was designed and delivered as part of a large-scale program rewrite. This PM course featured senior engineers with substantial PM experience, providing their reflections and knowledge related to 'that weeks' PMBOK topic. This was provided pro-bono by each presenter in response to a "mail out" seeking their input. In response to our request, some 35 industrialists responded for the 12 available lectures, demonstrating a willingness from local industry to engage with the University. The input from these industry people was well received by the students, as it gave them an immediate and tangible perspective on the reality of PM requirements.

The use of industry based "junior PMs" was likewise received well by the students, as these tutors brimmed with credibility in the PM space.

The mock projects from which the students developed (and presented a PM Plan for) were of sufficient quality that external reviewers needed reminding that these were not active projects.

Students reflecting back on the course after the completion, have commented that the practice skills in presenting and reporting have made a positive impact in their studies.

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The Effectiveness of Virtual Laboratories for Electrical Engineering Students from Faculty and Student Perspectives

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CONTEXT This research is focused on understanding the role of virtual laboratories and physical laboratories, specifically in the context of the electrical engineering discipline. It is important to emphasize that the research is not aimed at replacing physical laboratories as they form an essential part of the education of electrical engineers, but focuses on how virtual laboratories are used to supplement learning in physical laboratories.

PURPOSE Specifically, this research aims to identify the important learning objectives and virtual laboratory design features, as well as how virtual laboratories supplement physical laboratories from both the student and faculty perspectives. Additionally, the important design guidelines for the implementation of virtual laboratories are explored.

APPROACH A mixed method approach was used in the research that included both qualitative and quantitative methods. A detailed literature review was performed, supplemented by multiple surveys of both students and faculty. A virtual laboratory was designed and implemented using the input of the students to better understand what users desire and require in their virtual laboratory and students provided helpful input to the development and refinement of the virtual laboratory. The results of the surveys, along with the findings in the literature and the findings from developing and implementing a working virtual laboratory were combined to address the research aims.

RESULTS In the literature, virtual laboratories have been found to be effective for students, particularly those with limitations, either physical or time-based, who may have difficulties with aspects of accessing physical laboratories and the associated scheduling. Instructors and technical staff may find virtual laboratories useful, but with additional challenges for set-up, maintenance and integration with coursework. Many studies argue the effectiveness of virtual laboratories but find disadvantages related to insufficient realism, ineffective groupwork capabilities, maintenance of the systems and a lack of appropriate skill set development for real-world situations. Advantages of physical laboratories included flexibility for students, more time for experimentation, fewer overcrowded classroom and lower costs than physical laboratories.

CONCLUSIONS From the surveys, it was determined that the concept of realism and teamwork in the virtual laboratory are most important to students. Realism supports students' abilities to meet learning objectives, such as experimentation, design, instrumentation and their ability to understand and replicate theoretical models, while teamwork skills improve their ability to be successful in the classroom and in their careers. For their virtual laboratory, they desire easy-to-use interfaces that are reliable and consistent, and help them to learn by providing feedback on errors and feedback from their tutors, as well as providing supplementary learning tools. Many students that were surveyed identified using the simulator to prepare for testing and the virtual laboratory gave them the opportunity to experiment at their own pace when time in the physical laboratory was more limited.

KEYWORDS Virtual laboratories, electrical engineering.

Introduction

Like many global industries, post-secondary education has seen a significant evolution over the past half century due to the influence of information technology. In particular, higher education at both undergraduate and postgraduate levels has seen considerable innovation in the means through which teaching is provided. While traditional delivery mechanisms such as lectures, laboratories involving real-world equipment and classroom examinations are still employed to a significant degree in higher education, they are being supplemented or replaced by technology-enhanced means such as online streaming of lectures, timed online examinations and virtual laboratories.

Such modern digital resources serve as tools for educators to enhance the quality of education whilst catering to the individual learning preferences of students. For instance, through traditional means of teaching, students may be limited geographically to the location of the classroom, whereas streaming of such lectures online frees them from such a restriction. This in turn, allows students to save time, manage their learning around a busy schedule with family, work and commuting. However, location is only one of the many limitations that digital education resources solve. Given the scalability of modern media, educators can provide teaching with reduced effort to large numbers of students. As a result, the fees for education can be lowered since delivery costs per student are reduced. The digital domain provides an enhanced delivery of education through visual, audio and information-gathering resources that are difficult to replicate otherwise in a purely non-digital domain.

On the other hand, there are some learning activities which are difficult to effectively replicate in an on-line environment. Engineering laboratories are one such activity, where on-campus delivery is still the dominant mechanism, and on-line delivery is in its preliminary stages. While various manifestations of education technology are highly capable from a functional point of view, the design itself must also address factors that are crucial to the learning process and crucial to skill development of electrical engineering students.

Background

The following definitions relate to educational laboratories where students build and investigate engineering structures to better understand their operation.

A *Physical Laboratory* is a traditional laboratory where students are physically co-located with the apparatus under investigation. Often (but not always) students perform their experiments in groups that are supervised and assisted by laboratory demonstrators. A physical laboratory refers to the traditional laboratories which are built upon real estate and have physical equipment (Budhu, 2002).

In a *Remote Laboratory,* students also perform their experiments on physical equipment, where control and data acquisition to the equipment is mediated by sensors and actuators which in turn are accessed by a web interface (Tawfik, et al., 2013). Students may still conduct the experiments together in groups supervised by a demonstrator, or they could access the equipment at times and places of their choosing.

A *Simulation Laboratory* is where students perform experiments using a computer simulation of a system. The simulator may implement a realistic model of a system (such as a simulated circuit breadboard into which simulated wires, components and meters are connected) or on a more abstract model (such as a circuit schematic).

A *Virtual Laboratory* is an umbrella term for both remote and simulation laboratories, i.e., any laboratory where access to the experiment is entirely on-line. A virtual laboratory is a laboratory experience without the physical laboratory (Keller & Keller, 2005). Virtual laboratories are programmed systems that can simulate the features and activities of the real experiments that are done inside a real laboratory (Harry & Edward, 2005); (Altalbe, Bergmann and Schulz, 2015).

In a virtual laboratory, experiments are conducted and controlled partially or totally by using computers, simulation and animations, and more recently with the use of mobile devices (Frank & Kapila, 2017). Various models of virtual laboratories differ in their level of replication of reality (Budhu, 2002). The "MIT iLab" system is an open-source software framework which supports online (usually remote) laboratory experiments (Hardison, DeLong, Bailey, & Harward, 2008). It was first developed for batch-mode remote experiments and has been recently extended to support interactive experiments with the addition of a highly configurable service of the laboratory resource scheduling, a huge and strong data storing system, and capability to support high bandwidth communication systems between the laboratory server and the client.

The International Federation of Automatic Control (IFAC) has been studying virtual and remote laboratories for over a decade, including a control education remote laboratory (Esquembre, 2015). The remote options at the RobUALab include robots, servers for the network and teleoperation, camera, and software for modelling, access control and the robot interface (Jara, Candelas, Puente, & Torres, 2011). Some of the earliest work with remote laboratories and robotics was developed at the University of Western Australia along with remote robotics developed in the Mercury Project (industrial robot arm with a camera) and the Telegarden Project (Jara, Candelas, Puente, & Torres, 2011).

Individual differences amongst students and relative openness of the laboratories are important factors to be considered while designing experiments. Quality of interface and level of social interaction are important aspects to be considered to meet the student needs (Jara, Candelas, Puente, & Torres, 2011). It is important that while designing such laboratories the perceptions of the relevant students should be considered. This is because the perception of realism can be manipulated to improve the effectiveness (Nickerson, Corter, Esche, & Chassapis, 2007).

The design of online group work and the teaching method should be conducive to improving its effectiveness (Koh & Hill, 2009). Features of the online environment, personal attributes of the learners, and the teaching strategies employed by the instructors impact the learning process (Koh & Hill, 2009). Frustration with working in online groups can lead to situations where members drop out of the interactions (Warkentin, Sayeed, & Hightower, 1997). Other important barriers hindering participation of students in online group work include lack of availability of time and students' preference for reading compared to discussing matters online (Fung, 2004).

The process of conducting an experiment on the system should be explained in simple terms and be easy to understand (Stefanovic, 2013). The software needs to have a good interface, should have multi-platform portability, and should offer modularity by allowing development of the program in parts. Further, it should be compatible with the available hardware and should align with the existing code (Stefanovic, 2013). Debugging and help options are important. Features, such as extendable program libraries, increase the flexibility of the system. Multimedia features are particularly important (Tiwari & Singh, 2011). However, ease of use of the interface is more important in the context of learning and cognition compared to smoothness of navigation (Budhu, 2002). Help features can provide real-time guidance and support (Keller & Keller, 2005).

Ideally, a virtual laboratory must include a real-life scenario from which the student can collect data in a realistic environment (Stefanovic, 2013). This is because, in effect, working with a simulation is like exploring an algorithm which tries to imitate the real world. The discoveries made in the process of experimentation may be those related to the algorithm. One approach makes the system appear to control like a real lab (Keller & Keller, 2005). The laboratory responds with a video of the experiment. Students can remotely control the system, watch the video and gather data at various points in the video. The software collects and presents the data gathered or generated by the students. This is different from the simulation where the data is already fed into the algorithm (Keller & Keller, 2005). Animation techniques, videos, and 3D models help make the system more attractive for the students (Babateen, 2011).

In (Balamuralthara, 2013), student feedback was obtained on attitudes towards computer-based laboratories and experimentation. When students were asked to rate important aspects of laboratories, the authors found teamwork to be the highest rated item by the students. Students indicated that teamwork was essential to successfully conducting an experiment. Besides rating teamwork highly, students also felt that having assistance from a supervisor or technician was important.

The Simulator

The virtual laboratory prototype was designed to be a breadboard simulator for electronic circuits (DC based) and allowed students to connect components like resistor, diode, LED, IC, inductor and power supply on the given platform in a manner much like a real breadboard. It allowed them to simulate the results in the form of current and voltages based on real mathematical data and formulas based on Ngspice. The app makes heavy use of modern web browser features like JavaScript, DOM manipulation, SVG graphics and AJAX. The tool is different from a standard simulator as it can be coded to work with real equipment so students can have the experience of being in a real laboratory. When there is a good camera with proper zoom, students can see the same results on their simulator as they see on the camera attached to physical equipment, making the tool a remote laboratory and a simulation laboratory.

The virtual electronic circuit simulation laboratory system is a process that enables users to assemble and simulate electronic circuit via the library of SPICE3f5. Electronic circuit components were designed to be dragged and dropped into place in the schematic drawing. The term UQEEVL refers to UQ Electrical Engineering Virtual laboratory which allows students, tutors and professors to interact remotely and conduct virtual versions of their experiments (electronic circuits) at any time and obtain required results. Additionally, they also help carry out experiments that cannot be performed in physical laboratories due to limitations in equipment. Once users log in, they can then create a new project and drag components into the schematic drawing.

The tool is designed such that users can create their own experiments, retrieve saved reports from the database, and share and edit experiments. The system also provides a chat option to ease communication with tutors, classmates and groups. Spice3 was installed on the university server and a trusted domain at EAIT was registered for the tool at UQ (https://virtual-laboratories.eait.uq.edu.au). Ngspice release 23 was installed and is based on three open source software packages: Xspice, Cider1b1 and Spice3f5. There was a need for three separate programs and these are explained below:

1. A custom Java-based circuit editor that operates using an Internet browser, and generates circuit diagrams and netlists that can be stored on a database as <any name>.cir, able to display simulation results.
2. A web-server application that enables students to store user's circuits and simulation results on a database, that can also communicate with the simulation package. An example of this is currently operating on the University of Queensland's webserver.
3. A simulation package that can create circuit netlists and produces circuit waveforms, voltages, etc. Users never access this package, only the webserver does. This also runs on a server.

After successful completion of the whole circuit, the system's intelligent logic layer will determine the mode of the circuit. The power source management, diode and resistors are stored with their corresponding values, properties. The collected data can thereafter be sent to the application server and via this server the whole data are processed using the SPICE3f5 library. The total circuit is solved and the simulation result is then sent to the user's browser window.

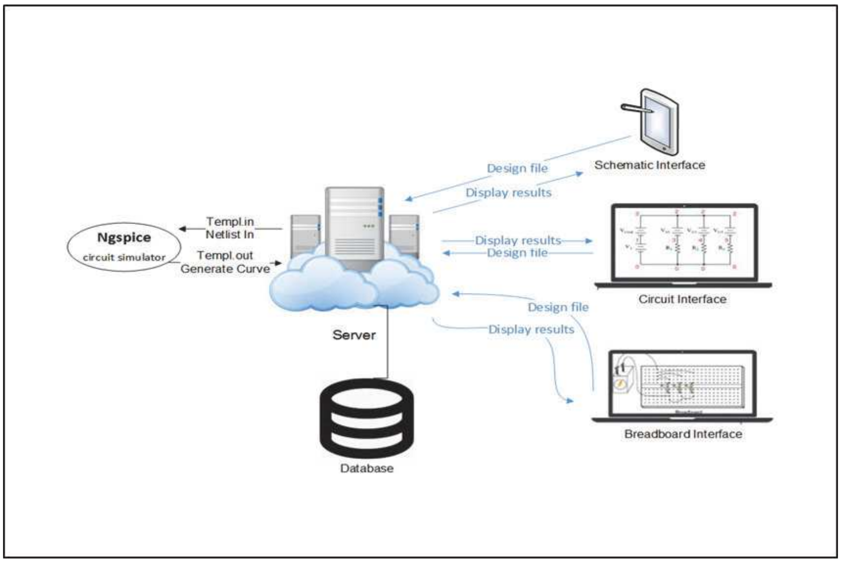

Figure 1: Lifecycle of the Simulation Software

Methods

In this research, a mixed method approach was used that consists of both qualitative and quantitative methods (Creswell, 2013). Firstly, a detailed critical analysis of the available literature was performed using a scoping study approach where a systematic review of existing literature related to virtual and physical laboratories is undertaken. Secondly, an experimental approach was employed by developing an example virtual laboratory to better understand the challenges related to the laboratory implementation. Thirdly, survey data and interviews were analyzed including the quantitative data and qualitative data.

Results

In the literature, faculty and student evaluations of virtual laboratories were mixed. Some students felt that computer experiences were not capable of replacing the physical laboratory experience and argued that computer screens are not capable of replacing many laboratory instruments. Collaboration in online environments was found to be frustrating for some students, but others felt their teamwork skills improved. Studies found that students find physical laboratories easier and more satisfying than virtual laboratories and that virtual laboratories are integral to traditional laboratories, but not a replacement.

Several studies in the literature advocated that the learning outcomes obtained in virtual laboratories are comparable to the outcomes obtained in the physical laboratory and for disabled students, and students in remote or rural areas, access to laboratories is now a reality. Educational leaders found it increasingly important to provide online learning, while for faculty, generating the exercises was found to be more burdensome. Again, the literature was somewhat mixed in that monitoring of students was found to be more difficult in one study, but others found that virtual laboratories improved the monitoring of students.

In the survey results, realism was the most important consideration of the respondents as shown in Figure 4, and indicates that a virtual laboratory should provide an experience that gives students the same capabilities that they have in the virtual laboratory. The students expressed desires for realism so that their education received in the virtual laboratory is comparable to the education they receive in the physical laboratory and that the skills developed are transferrable to a real-world setting. The ability of a virtual laboratory to supplement physical laboratories appears to be highly dependent on the concept of realism.

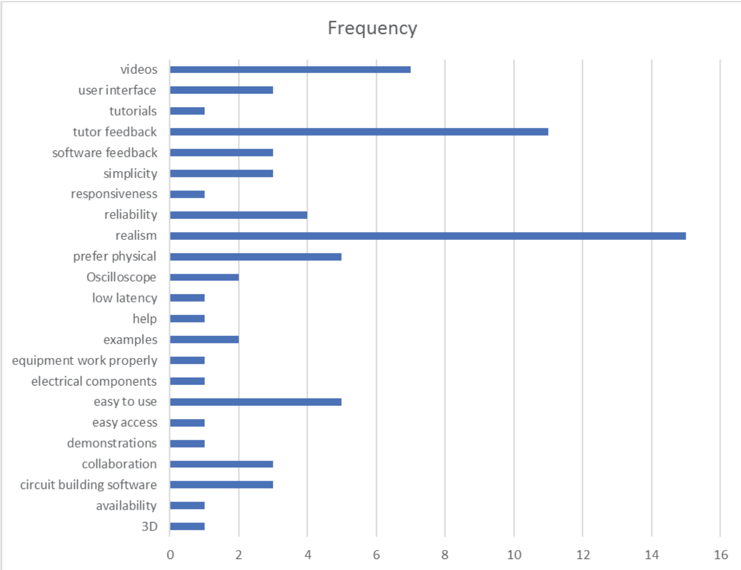

Figure 2: Analysis of Open Ended Survey Responses

Around 7% of the respondents indicated that they were more interested in using a physical laboratory as opposed to any virtual laboratory. While overall, most respondents were excited about using the simulator, it is important to note that there is a contingent of the student population that prefers the experience in the physical laboratory. Some of the student responses were quite adamant about their desire to work in a physical laboratory, including the following:

- *"I would not want to use virtual laboratories. I am paying to learn how to use equipment in the real world. It is of no use to me if I am using a virtualization of a physical device, if I have not understanding of how it works in the real world."*

One student commented, although not an advocate, that virtual laboratories are highly relevant in the cases of hazardous circumstances or where the real-world application of the skills require use of a virtual or remote operation of equipment.

From the comparison survey of virtual laboratories to the Breadboard simulator, it was found that students were using the Breadboard in timeframes associated with exams and rated using the Breadboard prior to an exam as the highest-ranking working style. Efficient use of time was the highest- ranking advantage. Some students found a very effective use of the tool by confirming physical laboratory work using the simulator prior to testing. The online setting provided the additional time to work and rework exercises however the results from the surveys fail to indicate that virtual laboratories can completely replace physical laboratories.

In the literature user interface, realism, individualization, storage capacity, social interaction, simplicity, multimedia features, help features and qualified technical staff were identified as important design considerations in virtual laboratories. Features identified in the surveys were the user interface, realism, real-time tutors, chat, online help, system response to errors, speed and reliability, message consistency, visual clarity, knowledge sharing capabilities, and individualized and group scheduling.

While social interaction is mentioned in the literature, real-time (or almost real-time) feedback and chat features are specific items mentioned by the students that do not appear in the literature. The use of error correction feedback was extremely important to the students as a design feature.

Discussion

The most important learning objectives for students were ***teamwork*** and ***learning from failures,*** skills that help students become more successful in the classroom and in their careers. Both the literature review and the survey results were consistent in finding that virtual laboratories need to provide ***realism*** for students to meet their learning objectives. Beyond what is currently in the literature, it was also found that students prefer to have online tools for communicating with their tutors and they would prefer that ***the interaction be in real-time***. Both real-time interaction with tutors and real-time corrections to mistakes were important to students.

A new finding in this research was that the ***students preferred to use the virtual laboratory to prepare for examinations***, which is consistent with concerns regarding time management. Students may not have sufficient time in the physical laboratory to master the concepts being presented, or may have difficulties scheduling laboratory-based classes due to institutional resource constraints. Another important finding, suggested by the students, was ***the need for virtual laboratories to prepare them for real-world situations where virtual or remote skills are necessary***. As technology has improved, engineers have more opportunities to respond to hazardous, or otherwise dangerous settings by using virtual and remote tools.

From this research, it would be difficult to argue that virtual laboratories can completely replace physical laboratories, but the students were found to be effective at using the virtual laboratory to improve their learning and supplement their learnings to perform better on their tests. They also point out the need to learn how to develop skills using remote and virtual environments that are currently necessary in real-world environments (for example, hazardous situations).

From the literature and the survey responses and interviews, this suggest the development of design guidelines, which are still under development. In summary, these guidelines suggest that a successful virtual laboratory deployment should (i) enable sharing of knowledge and real-time feedback, (ii) enable options for individualized learning and group scheduling, (iii) provide an intuitive user interface that is simple and easy to use, (iv) provide visual clarity in the user interface, (v) provide speed and reliability, (vi) provide functionality for experimentation, (vii) provide consistent messages and message positioning, (viii) provide system responses to errors, (ix) provide realism, (x) provide real-time access to tutors, (xi) provide online help and (xii) provide an environment that supports the physical laboratory.

Limitations and Future Work

The surveys and interviews are specific to the participants and users of the laboratory in this research, so the findings must be understood as such. There are a wide variety of online learning systems that are tailored to different academic programs, where opinions of their usefulness may be much different. While there were no findings presented in this research that deviated severely from previous findings in the literature, it is possible that students and faculty that chose not to respond may have had much different responses than the students and faculty that did respond.

The measurement of realism in the virtual laboratory and how it is measured would be a useful area of research. Perception-based measurements may be useful, supplemented by quantitative techniques for calculating the deviation of a virtual environment from a physical environment. As commercialization of the tools increases, a standardized measure of realism could be developed.

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Worked Example Videos as a Valuable Blending Learning Resource in Undergraduate Engineering Units

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Within many maths-heavy (MH) undergraduate engineering units (UEU), teaching teams rely on written worked-solution documents to assist students in bridging the gap between tutorials and self-directed study. However, these are limited in their usefulness as they are a passive medium and poor at communicating the 'why' required for deeper understanding. Alternatively, worked-example videos (WEVs) involve an instructor demonstrating a solution while discussing the underlying strategies being employed. The audio-visual medium encourages increased interaction with the content, promoting cognitive processing and improving the quality of student learning. Limited studies have investigated the potential for WEVs as high-quality blended learning resources in UEU. Better understanding of WEV impact could lead to their widespread use in the blended learning transformation.

PURPOSE To explore the impact of WEVs in MH-UEU by investigating student-video usage, interaction, and attitude, and the resultant effect on perceived academic performance.

APPROACH WEVs were produced weekly for two MH-UEU at the Queensland University of Technology. Student engagement, perceived academic performance and attitude toward the WEVs were evaluated using a mixed methods approach incorporating viewership data and an end-of-semester survey. The study comprised 1,713 students across five cohorts over three semesters.

RESULTS Students engaged significantly with the WEVs with almost 24,500 views and 89 days of continuous viewing time across the five cohorts. Exam preparation was the dominant motivator for WEV usage. Approximately 90% of students used an active learning style when interacting with the WEVs, with many taking advantage of video controls like pausing, skipping and rewinding. This enabled students to work alongside the WEVs, using them to provide hints and verify solution processes, as well as concentrate on specific sections of the WEVs, thus individualising their learning to focus on areas they found challenging. The majority of students agreed WEVs improved their knowledge of the unit content, had the potential to improve their grades, and would be useful in other similar units.

CONCLUSIONS WEVs are a valuable blended learning tool, capable of empowering student learning and enabling deeper engagement with problem solving tasks. Student interactions with the WEVs suggest that they are well-suited to MH-UEU where worked examples are an important learning tool.

KEYWORDS Worked example videos, blended learning, supplementary videos

Introduction

Engaging students in curriculum is a perpetual challenge, which is now being confronted by the move away from traditional lecture and tutorial delivery into the online space (Whatley & Ahmad, 2007). Blended learning, the combination of face-to-face and online instruction (Garrison & Kanuka, 2004), is the new expectation for engineering education. One opportunity of blended learning is the introduction of worked-example videos (WEVs) to complement the traditional written worked-solutions provided in maths-heavy undergraduate engineering units (MH-UEU). Considerations must be made for how online resources impact on the student experience and learning outcomes. Yet, there has been limited study into the integration of WEVs in UEU. This study will investigate the impact of introducing WEVs into two semester-long UEU. Their impact in terms of student engagement, attitude and achievement, will be evaluated to understand whether WEVs are a suitable blended learning resource for integration into existing units.

Background

Videos are a popular method for delivering online experiences (McGarr, 2009). The rise in their use has been enabled by the advent of YouTube and the accessibility of recording devices like smart phones and tablets, which has made videos cheap and easy to produce (Kay, 2012). Based on a comprehensive literature review by Kay (2012), most videos in the tertiary context have been recorded lectures and audio-overlaid PowerPoint presentations. These video types do not represent innovative approaches to developing online resources, as each mimics a passive classroom experience with little potential for encouraging active learning like group discussion, practice or teaching others (Prince, 2004). This approach to blended learning is counterproductive as video lectures have been shown to be less engaging than face-to-face lectures (Foertsch, Moses, Strikwerda, & Litzkow, 2002) and can serve as direct replacements for classroom experiences leading to reduced class attendance (Wieling & Hofman, 2010). Despite this, there is benefit in the convenience that these videos provide students in terms of ease of viewing and flexibility, as well as for instructors for ease of production and inclusion into existing courses (Wieling & Hofman, 2010).

Another type of video resource is the worked-example style, where mathematical-based problems are worked through step-by-step while the instructor narrates the process (Kay & Kletskin, 2012). WEVs gained significant recognition through the rise of ‘Khan Academy’ (Khan, 2016) which has become a major educational resource over the past decade by producing short WEVs on a wide range of topics. However the study of their impact in the tertiary education context has been limited (Kay, 2012). With regard to undergraduate engineering, Wandel (2009) and Wandel (2010) produced WEVs targeted at external students of thermodynamics. Belski (2011) and Belski and Belski (2013) studied the effectives of traditional written solutions compared to WEVs, as well as knowledge transfer improvements for an electronics unit. Martin (2016) used videos to demonstrate examples in an electrical engineering unit, however only a handful were made available which were not completed in class. Student cohorts were less than 100 in each of these studies. Thus there is a gap in evaluating the impact and value of WEVs in blended learning for large units.

WEVs show promise for blended learning because they can meet students at their point-of-need when practicing during their self-directed studies outside of class, making them an excellent resource for complementing face-to-face instruction. In fact, start-ups have begun targeting this space with companies such as ‘SpoonFeedMe’ emerging as providers of video summaries for specific university courses (SpoonFeedMe, 2017). Video explanations are superior to the written solutions traditionally provided for self-directed practice, as written solutions are unable to effectively convey the underlying problem solving strategies and thought processes used to develop a solution. Instead, students must infer from the lines of working why the process has been done a certain way, with students who are unable to reason this tending to solve related problems with ineffective and erroneous techniques

(Clement, Lochhead, & Monk, 1981). Unsurprisingly, research indicates that learning requires both visual and audio cues to best promote cognitive processing (Whatley & Ahmad, 2007). WEVs can take advantage of this as well as address the major issues associated with other video types. Incorporating WEVs into self-directed study encourages active learning whilst providing a different experience to that in the classroom, making it a genuine blended learning approach.

Methodology

To investigate WEV impact, a study was conducted across three semesters involving two UEU at the Queensland University of Technology; these units were Dynamics (Dyn) and Mechanics (Mec). Dynamics is a second-year course taken by students in the mechanical engineering stream which introduces the concepts of dynamics for particles and rigid bodies, while Mechanics is a first-year course taken by all engineering students concerned with the physical behaviour of structures subjected to forces. Both units focus on mathematical-based problem solving. All students were based on-campus with the face-to-face contact hours listed in Table 1. Attendance was not enforced and lectures were recorded and made available online. The assessment items for each unit are shown in Table 1, where it is noted that the problem solving task, quizzes and final exam directly assessed problem solving skills with short mathematical-based questions. Dynamics was the first unit to incorporate the WEVs in Semester 1, 2016 with WEVs incorporated into Mechanics the following semester. Data has subsequently been collected for three cohorts of Dynamics and two cohorts of Mechanics.

Table 1: Unit comparison

Attribute	Dynamics	Mechanics
Face-to-Face Contact Hours per Semester	Lectures: 2 hours/week (main) and 1 hour/week (maths supplement) Tutorials: 1.5 hours/week Computer Labs: 5 x 2 hours	Lecture: 2 hours/week Tutorials: 1.5 hours/week Experimental Labs: 2 x 2 hours
Assessment Items	Problem Solving Task, Computer Lab Assignment, Final Exam	3 × Online Problem Solving Quizzes, Group Design Project, Final Exam
Cohorts	Dyn-1: Semester 1, 2016 Dyn-2: Semester 2, 2016 Dyn-3: Semester 1, 2017	Mec-1: Semester 2, 2016 Mec-2: Semester 1, 2017

A set of WEVs were developed for each unit, such that each video focused on a single mathematics-based engineering problem, usually selected from the textbook, which aligned with the key content covered in face-to-face classes. Typically three to four WEVs were produced for each weekly topic, with the problems chosen such that they ranged in difficulty from simple to challenging. WEVs were structured to guide and enhance student learning. Each WEV opened with the question being introduced by the instructor, who then broadly discussed the problem solving approach to be employed, before working through the example systematically step-by-step by writing on the screen. Audio was used to narrate the process, emphasising connections between steps and the underlying principles as recommended by Clark and Mayer (2008). Common mistakes and misconceptions were clarified. Diagrams and visuals were used where appropriate to better communicate key concepts (Mayer, 2001). Videos were typically five to twenty minutes long. The videos were released to students at the end of the relevant week as a supplementary follow-up activity.

The WEVs were styled to break down the barrier between the instructor and the viewer, to maximise engagement and thus encourage active learning. In line with this, the WEVs incorporated a conversational communication-style, with tone and language representative of a tutorial where the problem is solved in front of an audience. This is supported by Mayer (2001) who advocates that a conversational approach is better for learning than a formal one, as viewers tend to feel that the instructor is engaging with them personally. To further enhance this, video editing was used sparingly, so the real-time thought process of the instructor was captured, maintaining the feel of a natural tutorial. The WEVs were kept as short as possible to maintain the attention of the viewers.

The WEVs were complemented by a 'recap' video for each topic which was similar to the summary presented at the beginning of tutorials. These summaries are also promoted in the literature as a useful tool for revising lecture material and for exam preparation (Whatley & Ahmad, 2007).

In terms of practical implementation, the videos were captured using a Microsoft Surface Pro computer with the pen accessory, using the software programs of Microsoft OneNote, Microsoft Screen Expression/Screencast-O-Matic and Microsoft Movie Maker. The videos were uploaded unlisted to a YouTube channel and then embedded within the learning management system (LMS) Blackboard.

A data collection strategy incorporating both quantitative and thematic data was used to assess student-video engagement, interaction and attitude as well as the impact of WEVs on perceived academic performance. Students were surveyed anonymously at the end of each semester to elucidate their interactions and attitudes towards the WEVs. The survey had 10 to 12 questions across a combination of checkbox, Likert scale and open-ended comment responses. The survey was available online and was estimated to take 5 minutes to complete. Thematic analysis was applied to student comments describing how they interacted with the WEVs with data coded manually into two major themes of video controls and prompting. The first dynamics cohort (Dyn-1) was not surveyed. Viewing statistics for all cohorts were collected from YouTube and the LMS.

Results & Discussion

To understand the impact and effectiveness of WEVs in MH-UEU, three main areas were analysed; viewership statistics, student interactions with WEVs and impact on perceived academic performance. Table 2 presents key metrics of the WEVs across the five cohorts. It is immediately apparent that students highly utilised the WEVs with a total of 24,478 recorded views, averaging 14.3 views per student. Views per student increased across consecutive cohorts. The increased viewership is attributed to improved awareness of the WEVs by the student body following a promotional drive by teaching staff. This was implemented in response to feedback that students were unaware the WEVs existed until late in the semester (a common problem experienced by other developers of WEVs, e.g. Kay and Kletskin (2012)). The time viewed per student is mixed for consecutive cohorts, which may be attributed to students selectively viewing sections of the videos discussed below.

To analyse this further, WEV viewership throughout the semester was explored (Figure 1). For Mechanics cohorts, two notable peaks in viewership were observed coinciding with quizzes held in weeks 4-5 and 8-9 (a third quiz was held in weeks 14-15 but this is hidden by end-of-semester study). The quizzes were only open for seven days which likely contributed to concentrated increases in viewership during these periods. Conversely, dynamics cohorts showed fairly steady viewership throughout the semester, with a slight dip near the end of semester when students were likely finalising assignments (weeks 11- 13). Interestingly, no major change in viewing is evident around the problem solving task due date (week 9) despite students reporting using the WEVs for this assignment. This may be because the assignment was released several weeks before the due date so assignment-related views were spread over a wide timeframe. Most significantly, a large peak is observed at week 15 for all cohorts, making up 57% of the total views. This peak corresponds to the final exam. These findings infer assessment is the largest driver of WEV viewership, which is largely unsurprising given that assessment tends to be a driver for student learning (Brown, 2005).

Table 2: Key metrics of WEVs across cohorts

Attribute	Cohort				
	Dyn-1	Dyn-2	Dyn-3	Mec-1	Mec-2
Students Enrolled	270	160	211	685	387
Total Videos	42	44	44	55	55
Total Views Recorded by YouTube	3408	2501	3393	8476	6700
Total Hours Viewed from YouTube	361	203	332	672	568
Average Views/Student	12.6	15.6	16.1	12.4	17.3
Average Minutes Viewed/Student	80	76	95	59	88
Survey Respondents	N/A	33	48	77	90
Response Rates %	N/A	21	23	11	23

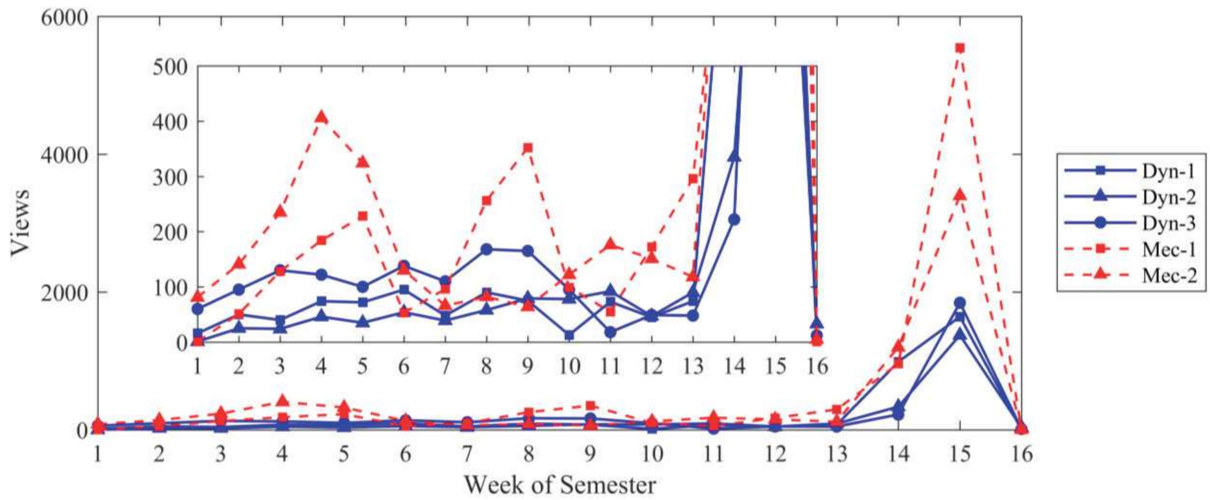

Figure 1: WEVs views per week from YouTube (inset zoomed in)

Hypothesising that WEVs encourage deep learning, student interactions with WEVs were investigated via the end of semester survey. Students were asked about their motivations for using the WEVs with results shown in Figure 2a. Both units show similar trends, with the vast majority of students reporting exam revision as a key driver; this is in line with the above viewership analysis. Despite assessment being the dominant driver for WEVs usage, between 30% and 50% of students reported using WEVs in an ongoing capacity during the semester for consolidating learning in face-to-face classes, to make up for missed classes, and to clarify understanding of challenging concepts. A small minority of students reported using the WEVs as a replacement for tutorial attendance. This suggests WEVs provide an effective blended learning experience which has minimal impact on reducing class attendance.

It is interesting that fewer students used the WEVs for assignments than for the exam. This may be explained by assignments setting a well-defined task compared to exams, for which students only know the broad topics being assessed. This means there is more value in reviewing a large number of problems for exams, such as those in the WEVs, in order to prepare for all possibilities. Furthermore, the assignments in both units tended to test content soon after it was taught compared to the exams which assessed content taught weeks in the past. Thus the WEVs became an excellent tool for systematic revision, supported by student

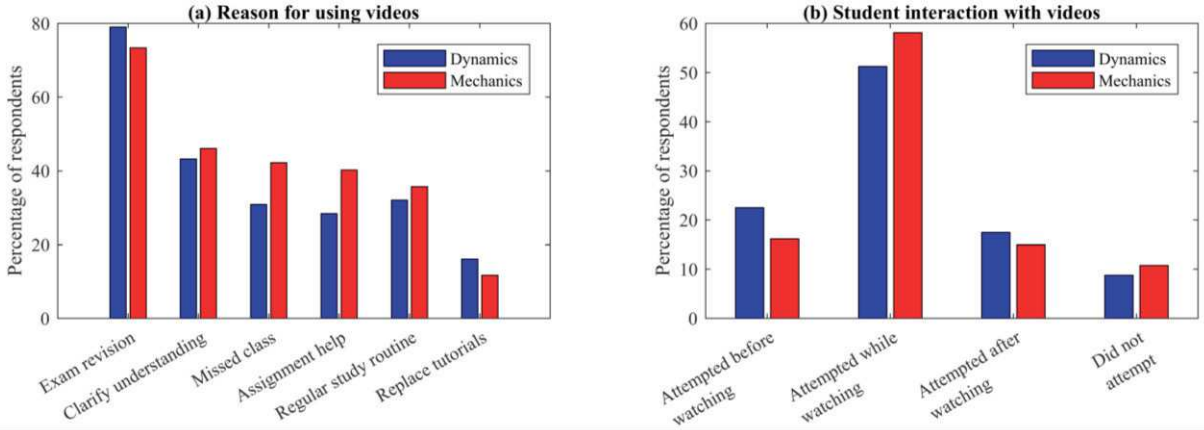

Figure 2: (a) Reasons students used the WEVs from survey responses, (b) Student responses to how they typically interacted with WEVs

comments such as, “I have looked at the videos as part of my revision … they are a great refresher.” This demonstrates WEVs are well-suited to units with significant final exams. The similarity of an assignment’s style to the WEVs can also help to pinpoint the types of units that would see the most engagement with WEV resources. In Mechanics, of the students who reported using the WEVs for assignment help, 98% said this was for the quizzes and just 25% for the group project. The quizzes asked questions similar to the WEVs, while the project was very different, requiring analysis of a structure for its cause of failure and then an open-ended redesign. Likewise, in Dynamics, of the students who reported using the WEVs for assignment help, 100% said they used them for the problem solving task and 64% for the computer lab assignment. The problem solving task asked questions similar to the WEVs, whereas the computer lab assignment required simulation of problems using software and comparison with hand calculations. This suggests WEVs are well-suited to units with assessment strategies centred on testing problem solving skills with questions similar in style to those presented in the WEVs.

Figure 2b shows how students interacted with the WEVs. Approximately 90% of students solved the examples before, during or after watching the WEV and thus employed an active learning approach, compared to only 10% of students who did not attempt the examples and consequently used a passive approach. This provides strong evidence that WEVs can facilitate active learning opportunities where students independently practice their problem solving skills. This is important as the shift from a receiving learning mode to a participating learning mode is linked to better understanding and knowledge retention (Prince, 2004).

To further explore student-video interactions, thematic analysis was conducted on open responses where students described how they interacted with the WEVs. The first major theme identified was using the video controls of pausing, rewinding and skipping. Students most frequently discussed using pausing to work alongside the WEVs with comments such as, “I paused throughout the video and attempted to move farther from there and if I was stuck I would continue with the video.” This is consistent with the earlier finding that the majority of students were attempting the questions while engaging with the WEVs. Skipping and rewinding were regularly noted as a way of focusing on the parts of a question which were most challenging. This was supported by comments like, “I usually skipped over easy parts and repeated watching the most important parts of solving the question.” This suggests WEVs can enable students to individualise their learning and review aspects they find challenging at their own pace. This self-paced learning afforded by the video medium has previously been identified as an area which students enjoy (Chester, Buntine, Hammond, & Atkinson, 2011).

The second major theme identified in the thematic analysis was prompting, with students using the WEVs to further their learning in different ways. Some students reported using the

WEVs to prompt their solution processes in real-time to give hints on how to proceed when they became stuck. This contrasted against others using the WEVs as reinforcement for their problem solving strategy such as, “Attempted sections at a time. So when a new part of the solution was about to start I would attempt it and then verify that I did it right with the video.” Some students reported using the WEV examples as a guide for attempting additional examples from the textbook, evidenced by comments like, “Watched the video and applied the theory to another question.” This implies the WEVs can serve as a launching pad for further study. This could be further encouraged by recommending additional practice problems related to each worked-example, which was in fact proposed by some students when asked how the WEV concept could be improved. These findings support WEVs as a means of encouraging active learning.

The survey also assessed whether students felt their understanding of engineering concepts had improved and if they would get a better grade from using the WEVs. The results are shown in Figure 3(a-b). This shows most students strongly agree the WEVs had a positive impact on their technical content knowledge, and they perceive this would result in better grades in the unit. This suggests WEVs can contribute to improving academic performance. Furthermore, students agreeing that their understanding had increased, suggests that they were not using the WEVs as a tool for memorising solution processes, but rather learning the content on a deeper level. Figure 3c shows student attitudes toward the WEV resources are extremely favourable, with the majority strongly agreeing that they would use WEVs if made available other similar units. This was also echoed frequently in the open responses, again strengthening the argument that these WEVs would be suitable for other units.

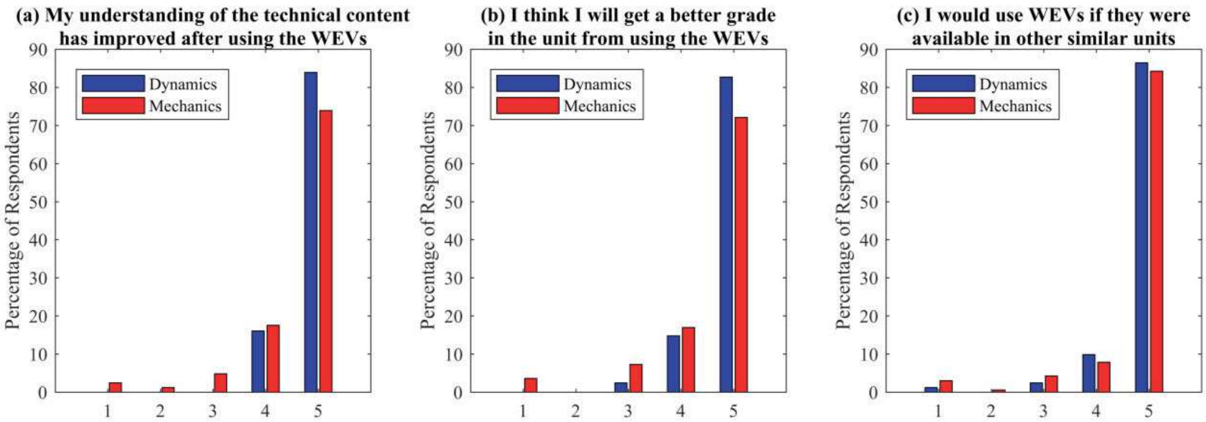

Figure 3: Likert scale responses to survey questions (1=strongly disagree, 5=strongly agree)

Conclusions

WEVs are well-suited to MH-UEU where solving worked-examples is a key teaching tool. Students are most likely to engage with the WEVs around the exam preparation period, with secondary engagement drivers being to reinforce content throughout the semester, make up for missed classes, clarify understanding of difficult concepts, and help for assignments which ask questions similar in style to the worked-examples. Only a small number of students reported using the WEVs to replace tutorials, indicating that the WEVs were primarily used to compliment face-to-face classes.

Students overwhelming interact with the WEVs using an active learning approach by independently working through the questions, often using the WEVs for hints when they get stuck and to verify their solutions. This is enabled by the video controls of pausing, skipping and rewinding which allow students to personalise their learning by concentrating on sections of the WEVs which they find challenging. Students report that they understand technical content better and expect to achieve better grades in the unit from using the WEVs. Students overwhelmingly agree that they would use WEVs if they were developed in other similar units. As such, it is shown that WEVs can be an effective tool for embedding blended learning approaches within MH-UEU.

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Ethics Approval

This research was approved by QUT's Human Research Ethics Committee (approval number 1600000165).

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Case study based teaching of process economics in the context of Chemical Engineering

SELECT SESSION (delete all but one session)

C3: Integration of teaching and research in the engineering training process

CONTEXT

A key area in the Chemical Engineering curriculum is process economics which forms the backbone of process design. Teaching and delivery of this unit may be difficult due to the diverse economics concept not familiar amongst engineering students. Another challenge in teaching process economics is that while the theory may be relatively straightforward, the application of the theory to real world situation is quite challenging. Students may also find the topic relatively 'dry' as parts of the topic may be quite empirical.

PURPOSE

Is there a way to enhance the delivery and teaching of process economics in the context of Chemical Engineering?

APPROACH

In this work, a case base approach to learning the theories of process economics was introduced. A large case study based on the economic evaluation of the construction of a dairy milk powder processing facility was introduced into the unit. The same case study will stretch over 5 weeks of lecture from which the students will cover the following concepts: market evaluation, capital cost estimation, operating cost estimation and profitability assessments. This is in contrast to teaching the theory and introducing smaller examples for each theory. This approach also encapsulates the research experience of the author of this paper and is relevant to providing a wider training to students for the dairy industry in Victoria.

RESULTS

This approach provided a more interesting approach to learning process economics with more focus on the application, rather than starting from a theoretical perspective. In learning process economics, the students also had a good exposure to the dairy industry which is one of the primary industry in Victoria. The class also benefits from the research experience of the first author, incorporating research experience into teaching.

CONCLUSIONS

The strategies described in this communication can be tailored for other examples specific to the expertise or experience of the lecturer. An important element to the implementation of this pedagogy to teaching engineering economics is to identify suitable large case studies which can be stretch across the whole delivery of the engineering economic course.

REFERENCES (OPTIONAL)

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KEYWORDS

Process Economics, Chemical Engineering, Case Base Approach, Dairy Processing

Introduction

A key area in the Chemical Engineering curriculum is process economics, which forms the backbone of process design. Teaching and delivery of this unit may be difficult due to the diverse economics concept not familiar amongst engineering students. Another challenge in teaching process economics is that while the theory may be relatively straightforward, the application of the theory to real world situation is quite challenging. Students may also find the topic relatively 'dry' as parts of the topic may be quite empirical. In order to improve the delivery of this type of unit to engineering students, a more applied approach is introduced in this communication.

Another challenge which may be faced when delivering a unit of this nature is that some students in the class may be coming from a double degree Commerce/Engineering background. In essence, these students would have covered and have learnt the basic economics theory in their commerce courses. Teaching such a unit starting from the theoretical approach will not be interesting for these students. Increasing the scope of the content or making the course more difficult to cater for the commerce students may also make the unit too difficult for engineering only students. Therefore one alternative is to have more applications form of teaching incorporated into the unit which will cater to both streams of students.

This communication describes and provides ideas on how this form of teaching can be introduced based on the revamping of a unit delivered in Monash University in 2017. The author will also share the experience, especially the finer details important in this form of application based delivery of the unit by the introduction of a large case study based discussion approach in lectures, completely replacing the traditional dictative type of lectures.

Challenges in the previous delivery approach

In order to better appreciate the case study based approach introduced in this communication, it will be important firstly describe the scope of the engineering economics materials covered listed below chronologically. This is important for the reader to better appreciate the strategies highlighted later on and to interpret for application to their own units:

1. Market Identification and forecasting
    a. What is a market – Supply/Demand
    b. Classification of markets: high/low demand, commodity, specialty etc.
    c. Different forecasting tools for demand volume
    d. Different forecasting tools for pricing
2. Capital cost estimation
    a. Stages of engineering economics evaluations
    b. Location selection
    c. Sources of capital or funding
    d. Tools to predict capital costs
        i. Equipment by equipment estimation
        ii. Whole plant estimation
        iii. Battery limits in capital cost estimation
        iv. Effect of location and inflation

3. Operating cost
    a. Variable costs (raw material, utilities, cleaning etc.)
    b. Fixed costs (manpower, overheads, administration, sales, research etc.)
    c. Working capital
4. Profitability evaluation
    a. Cash flow estimation
        i. Taxes
        ii. Depreciation
        iii. Inflation
        iv. Non-cumulative/cumulative cash flow estimation
    b. Net present value estimation
    c. Project payback period
    d. Economic risk assessment

Before the revamping, these topics were typically covered via 12 hours of lecture over 4 weeks. The syllabus for the engineering economics listed above constitute one-third of a larger unit which also focuses on process safety and environmental management. The current scope of the engineering economics materials covered were mainly focused on the forecasting in the context of building a manufacturing facility. It does not put emphasis on other aspects of engineering such as production management and product development etc. which will also require engineering economic analysis (Walter 2008).

These materials were mainly covered by firstly going through the theory and then followed by short examples or application for each theoretical section covered. The examples were mainly not related to each other. Such an approach may effectively cover the theoretical aspects adequately, however, it may not give the students opportunity to link up these ideas. It is also noteworthy that theoretical aspects of these topics are rather empirical. Therefore, there is minimal value to teach these concepts theoretically (it would have been very boring too to teach!). The assessments for the engineering economic section involves:

1. Group Assignment on market evaluation
2. Group Assignment on cost and profitability estimation
3. Written exam with part of the exam covering engineering economics

Single large case study replacing lecture approach

The delivery of these units were then revamped by introducing a large engineering case study from which these concepts were introduced. This also ties in closely with the intended outcome of the unit as students are expected to know how to apply these concepts in evaluating the economics of engineering projects. Switching from a traditional theoretical approach to engineering economics to a case study approach has been reported and described by several reports in the literature (Manohar 2012, Russ and Nance 2004, Brunnhoeffer III 2017). Most of these papers suggest the use of different case studies in the weekly delivery of the unit followed by discussion of the cases in or out of lectures or as additional group projects outside of lecture. One report suggested the implementation of a game, in the opinion of the author analogous to case studies albeit a significantly more interactive approach, as an additional component complementing traditional lectures (Dahm 2002). There was also a report in the literature in which slightly larger case studies were introduced stretching across half of the teaching semester (Barsanti 2011). In these reports, apart from the approach by Barsanti (2011), regardless of the different forms in which case study was introduced, students had to firstly learn the theory in class before attempting the case studies. The current report differs from those described in the literature and aimed at using case study discussions as the main teaching medium without the need to students to firstly learned the theory: the theory only formalized and introduced only after the case study discussion. In addition, only one significantly large cases study, which stretches across the whole delivery period of the engineering economics section of the unit. The main hypotheses were: Will a “case study discussion first” approach be more effective in teaching engineering economics? Will a large case study help students link the different materials better?

In order to assess these hypotheses, the other aspects of the engineering economics part of the unit was deliberately maintained the same the previous year. Please refer to the section above for more details. The main difference was that the traditional lectures have now been converted into the discussion of the large case study. This is completely flipping the delivery approach in contrast to some approaches report in the literature where case studies were added as an additional component to complement traditional lectures (Manohar 2012). For this, the discussions of the case studies were not assessed and there is no marks attributed to the large case study introduced.

Drawing from the experience and familiarity of the author, a case study in the evaluation of the construction and operation of a skim milk powder manufacturing facility was introduced. Students also get to concurrently learn in greater detail of the economics, operation and technical aspects of the dairy industry which is a major industry in Victoria. The new structure below was then introduced. The headings provided are key sections of the lecture (or questions) delivered to the students over 4 weeks.

1. Market Identification and forecasting
    a. What are the markets which can be derived from raw milk? (Supply/Demand, classification of markets)
    b. What is the outlook of skim milk and full milk powder demand over the next 10 years? (Market volume forecasting)
    c. What is the market value of skim milk and full milk powder over the next 10 years? (Price forecasting)
2. Capital cost estimation
    a. Who will be the stakeholders and decision makers in the skim milk plant project? (stages of engineering economic evaluation)
    b. Should we build the skim milk powder plant in northern, eastern or western Victoria? (location selection)
    c. Should we release bonds, inject capital, search for angle investors, or go IPO to get capital for the project? (sources of capital)
    d. Let us estimate the cost of the project based on some similar large projects implemented in New Zealand (whole plant estimation + inflation)
    e. Let us double check the rough estimation with a equipment-by-equipment cost estimation (equipment-by-equipment estimation + inflation)
    f. How about we build this plant in China? (effect of location)
3. Operating cost

   a. How much milk do we need for the skim milk powder plant? (raw material costs)
   b. What is the energy requirement in a skim milk powder plant? (utilities)
   c. What is clean-in-place (CIP) strategies in a plant and waste management strategies? (utilities and waste management costs)
   d. How many operators and additional personnel are required to operate the plant? (manpower and overhead– fixed costs)
   e. What happens if we need to ramp up or down the production capacity dues to seasonal variations? (Working capital)
4. Profitability evaluation
   a. How much tax do we have to pay based on our estimated skim milk powder plant operation? (taxes, depreciation, non-cumulative cash flow)
   b. When will we get back our investment on the skim milk powder plant? (cumulative cash flow and payback period)
   c. Should we be investing our capital in other investment tools or opportunities? (Net present value estimation)
   d. How will the fluctuation in milk price or demand affect the outlook of the project? (economic risk evaluation)
   e. What is inflation and how it affects the engineering economic evaluation. (inflation)

It can be seen that the new structure is actually a series of discussions revolving around a large example in which the student will repeatedly go through. The theory covered under each discussion is listed in brackets next to the topic of the discussion. These topics are delivered as discussions and the students are only informed of the theory after the discussion. While these questions for discussion may change depending on the case study used, it is the intention of the authors to illustrate the approach and to give an example to the reader on how these topics can be flipped. The rationale for this pedagogical approach, the challenges in which it was intend to overcome for each particular topic, is given in Table 1. For brievity, the technical content of these individual section and not included and interested readers are directed to the reference cited here (Brennan 1998).

Referring to Table 1, for components of the syllabus in which the theory was relatively too empirical, students may find it difficult to selection correlations and empirical constants suitable for specific economic estimations. By flipping the delivery of the content, students can firstly examine a real (and real numbers) before making comparison with the empirical theory. This was intended to help students make better judgement of the empirical tools available in engineering economics. While Part 4a,b are not empirical in nature, students may find these fundamental theory complex this would be the first time they are exposed to economic term and concepts; they may not have the 'sense of money'. Therefore, similarly, the rationale was to start introducing these concepts by examining real numbers (from the case study) which they would have generated by themselves over the past few weeks of the course. Theory for Part 2a,b,c are relatively very general and in the opinion of the author, there is little value in teaching them in detail. The value in theory introduced in Part 2,a,b,c lies in better understanding the constraints when applying them and these are best introduced in the form of a real case study.

Additional observations

For single degree engineering students, there was significantly more questions asked during lectures in Part 4 when compared to the other parts of the course. This is especially in grappling with how depreciation affects tax calculation. In fact, additional lecture time was allocated explaining depreciation from the perspective of 'book keeping practice' and it actual tangible meaning. Interestingly, throughout the semester, there was feedback from double degree engineering/commerce students that the application approach actually helped them understand better the depreciation-tax concepts, which they had learned in the commerce units (verbal feedback from two students after the lectures).

From the questions raised in class, when delivering of the net present value concept, there was significant confusion amongst the student on the difference between calculating the total net present value and the internal rate of return of a project. Details on these concepts can be obtained from any engineering economics textbook (Brennan 1998). The strategy devised in the delivery of this unit is to explain that both concept utilizes the same theoretical framework in calculating net present value. The only different is that total net present value evaluation utilizes a fixed rate of return as a basis for comparison whereas the internal rate of return evaluation utilizes a zero total net present value as a basis for evaluation. In the opinion of the author, this set of explanation seemed to provide a logical approach to link these two concepts.

Table 1 Rationale of the introduction of the new pedagogical approach

Section of the syllabus based on the previous delivery approach	Challenges in the previous approach	How the new approach aims to overcome the challenges
1 a, b, c, d	Theory too empirical	Examine real cases and numbers first to better appreciate the empirical theory
2 a, b, c	Concepts too general	Examine the constraints in the concepts via a case study and significantly minimise the theory part of the delivery
2 d	Theory too empirical	Examine real cases and numbers first to better appreciate the empirical theory
3 a, b, c	Theory too empirical	Examine real cases and numbers first to better appreciate the empirical theory
4 a, b	Theory may be complex for some students	Students to firstly work with monetary values generated by themselves (better familiarity) before the introduction of the theory

Student evaluation and on-going work

There was no formal and specific survey or class feedback undertaken to evaluate this change in the teaching pedagogy. The overall evaluation for the unit following Monash University's general unit evaluation system was, however, slightly lower when compared to the previous year (Table 2). It is noteworthy that the engineering economic part of the unit constitutes only one-third of the whole unit and it was unclear if the evaluation score directly reflects the the changes undertaken for the engineering economic part of the unit. Anonymous qualitative feedback from the students also did not specifically addressed the use of the new pedagogy. The actual detailed feedback was not included here for confidentiality. In general, the were comments that the delivery of the engineering economic part of the course helped in understanding of the tricky financial concepts. Surprisingly, most of the comments for improving pertains to the huge number of slides used to guide the discussion during the lecture session; comments which is not related to the pedagogy used. It is noteworthy that the use of the large number of slides were meant to 'flip card' animate the presentation. Students did not like this mainly due to the difficulty in printing the slides. More specific quantitative survey will be undertaken in the upcoming semester.

In addition to addressing the comment from the student survey, from the additional observations above on the difficulty faced by students in Part 4 of the materials covered, there is now on-going work to put more emphasis on this area in the upcoming semester. This will be balanced by reducing the time allocated to the teaching of economic factors and the mathematics involved in the unit. This also follows the pedagogical change discussed by Ristroph (2009) highlighting for stronger emphasis on areas such as tax (which is affected by the computation of depreciation) and inflation.

Table 2 Student evaluation of the whole unit (0 – lowest, 5 – highest)

Evaluation questions	2016 (previous approach)	2017 (pedagogical change)
The Learning Outcomes for this unit were clear to me	4.18	3.98
The instructions for Assessment tasks were clear to me	4.05	3.93
The Assessment in this unit allowed me to demonstrate the learning outcomes	4.10	4.07
The Feedback helped me achieve the Learning Outcomes for the unit	4.06	3.57
The Resources helped me achieve the Learning Outcomes for the unit	4.04	3.75
The Activities helped me achieve the Learning Outcomes for the unit	4.11	3.91
I attempted to engage in this unit to the best of my ability	4.22	4.07
Overall, I was satisfied with the unit	3.99	3.70

Conclusion

The strategies described in this communication can be tailored for other examples specific to the expertise or experience of the lecturer. The principle is to use a large example in which the student can repeatedly discuss throughout the semester. Another main strategy introduced here is to run the lectures as a form of discussion and only introduce the concept as an 'artifact' from the discussion. This strategy will make the largely empirical or qualitative nature of most of the engineering economic concepts more interesting. When implementing this approach, readers are advised examine the two 'lecture schedules' provided above as a guide on who to modify the theoretical content of the lectures in to suitable discussion topics for the large case study. It is noteworthy that the pedagogical approached introduced here uses the large case study to replace lectures and not an additional components or assessment to lectures. Lastly, feedback from single degree engineering students indicate that the most enjoyable outcome from a unit of this nature is that it exposes them to economic concepts, which they have not considered before. It is the opinion of the author that this should be the main aim of engineering economic units, which is to focus on providing exposure to students to a breadth of economic concepts, rather than focusing on the 'nitty-gritty' details of economics. Such philosophy, if adopted, should also be reflected in the type of assessments developed for the unit.

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Can Idea Generation Techniques Impede Effective Ideation?

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SESSION S2: EDUCATING THE EDISONS OF THE 21ST CENTURY

CONTEXT Recent research has demonstrated that simple idea generation (ideation) techniques can assist students to generate a significantly higher number of ideas relative to an equivalent control group (Belski et al., 2015), and that students can learn to effectively apply ideation techniques using either a pen-and-paper or computer-based approach (Valentine, Belski, & Hamilton, 2017). This raises the question of how applicable the findings of these studies may be to other ideation techniques in general, and whether certain ideation techniques may actually demonstrate no effective increase in performance, or demonstrate a difference in performance between pen-and-paper or web based approaches. In order to adopt ideation techniques into courses covering creativity or problem-solving, educators should ideally ensure that the techniques in question have been shown to be effective, based upon the outcome of empirical studies.

PURPOSE To establish whether the findings of Belski et al. (2015) and Valentine et al. (2017) may be expanded to incorporate a secondary simple ideation techniques such as Size-Time-Cost Operator, or whether the findings may only be limited to the Fields of MATCEMIB technique.

APPROACH A simple TRIZ (Russian: teoriya resheniya izobretatelskikh zadach, English: theory of inventive problem solving) based ideation heuristic (Size-Time-Cost Operator) was selected for the study, and a pen-and-paper and equivalent computer-based worksheet template designed to guide a person through implementing the technique, were created. Seventy-nine engineering students were allocated into one of three groups; a control group (provided with no external guidance), a group which utilised the pen-and-paper Size-Time-Cost template, or group which utilised the computer-based Size-Time-Cost template. Students were presented with a creativity problem and provided with ten minutes to generate as many ideas as possible. Student performance was then assessed based on the number of distinct ideas and diversity of ideas, and the average performance of each group compared.

RESULTS Results showed that students generated an average of 5.03, 5.04 and 4.20 distinct ideas for the control, pen-and-paper and computer based groups, respectively, and that there were no significant differences between any of the groups for the number of ideas generated, or diversity of ideas. These outcomes do not challenge the findings of Valentine et al. (2017) that students can apply ideation techniques equally effectively using either pen-and-paper or computer, but did not find any difference between control and experimental groups as found by Belski et al. (2014).

CONCLUSIONS The outcomes of this study suggest that certain ideation techniques may not always help a student to perform statistically significantly more effectively, compared to a control group. This reinforces the need for educators to ensure the techniques they aim to introduce are first shown to be empirically effective, and that educators need to emphasise that while heuristics may not always lead to a solution, certain heuristics may be more suitable than others for maximising the chances of the ideation phase being successful.

KEYWORDS Computer-based learning, ideation, TRIZ

Introduction

The ability to be creative and show innovation have been demonstrated to be important for graduates in the field of engineering, with studies reporting that engineering employers place value upon the ability to be able to effectively demonstrate competency in these skills (Male, Bush, & Chapman, 2010; Nair, Patil, & Mertova, 2009). The ability to be creative is primarily concerned with being able to think of novel (i.e. original, non-obvious), useful solutions to resolve a situation (Cropley, 2015), a situation often faced when presented with a new or unfamiliar problem. Creativity therefore relies heavily on the process of idea generation (ideation). Ideation is considered to be a main stage of the problem solving process, according to numerous models which depict the problem solving process (Belski, 2002).

Research has highlighted several concerns within engineering curricula, which can make it difficult for engineering students to effectively demonstrate and enhance their creativity skills. When generating ideas to resolve a new or unfamiliar problem, students will often conceptualise an initial idea and then find it difficult to think of additional ideas (Condoor, Shankar, Brock, Burger, & Jansson, 1992; Kershaw, Holtta-Otto, & Lee, 2011; Samuel & Jablokow, 2010), a phenomenon known as design fixation. Many students become quickly satisfied with the immediate result and move on with the idea they have produced, rather than spending more time searching for other possible solution ideas (Samuel & Jablokow, 2010). Spending only a short time searching for ideas to resolve a problem makes it more likely that ideas which may be more suitable, effective or profitable will be missed during the ideation process. This can severely limit a person's ability to be creative.

Educators may consider how this challenge may be met, to assist students to overcome these issues and to effectively build their creativity skills. Instead of implementing large scale curricula reforms or designing courses that are dedicated to teaching creativity skills, alternative solutions may be appropriate. One suggestion is that students may be exposed to short (less than an hour duration) creativity related activities throughout the duration of a degree (Belski, Hourani, Valentine, & Belski, 2014). Belski et al. (2014) argue that such activities may be integrated into existing courses such as those on engineering design, and that exposure to such tasks may be an effective method to teach students creativity skills while meeting restrictive curricula restraints. Meta-reviews have previously investigated the effectiveness of creativity training on training participants, and established that creativity training generally results in enhanced creativity levels for involved participants (Scott, Leritz, & Mumford, 2004; Tsai, 2013), suggesting this idea may have credence.

Over a series of replicated experiments, it was consistently shown that introducing students to a simple ideation technique enabled them to perform more effectively when faced with an unfamiliar problem, than a comparable control group (Belski et al., 2015). Moreover, it was demonstrated that exposing students to ideation techniques which do not take much time to learn, can have measurable long term benefits to creativity performance even after an intermittent period of several months (Valentine, Belski, & Hamilton, 2016). These outcomes were expanded upon by Valentine et al. (2017), who demonstrated that students are able to apply ideation techniques equally effectively using either a pen-and-paper or computer-based approach. This outcome lead to the suggestion that self-contained web-based tools may provide a suitable means to enable students to engage in learning ideation techniques, and that this may also be done without requiring educators to provide class time.

Although the results of these studies are encouraging, there is one major limitation. In the empirical studies conducted (Belski et al., 2015; Valentine et al., 2016, 2017), the ideation techniques used have primarily been limited to the Fields of MATCEMIB (Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular, Biological) technique, and Substance-Field Analysis technique, which is heavily based upon the Fields of MATCEMIB technique (Belski, 2007). This raises the question to what extent the findings of these studies may be expanded to incorporate additional ideation techniques, or whether the findings may only be limited to the Fields of MATCEMIB. In particular, it was of interest to know whether an alternative simple ideation technique can lead to improved performance over a control group, and whether students may also effectively implement alternative simple ideation techniques using a computer-based or pen-and-paper approach.

Methodology

Size-Time-Cost Operator

To establish whether the findings of Belski et al. (2015) and (Valentine et al., 2017) may be expanded to include a secondary heuristic, selection of an alternative ideation technique was required for this study. Size-Time-Cost Operator is a TRIZ (Russian: teoriya resheniya izobretatelskikh zadach, English: theory of inventive problem solving) heuristic that is used for framing and re-framing problems. The heuristic encourages a practitioner to consider the situation of interest from six alternative new scenarios, and what they may do to resolve the problem under these new conditions. These conditions include scenarios where the practitioner (i,ii) may use or make something very large or very small in size, (iii, iv) has infinite or zero time to resolve the problem, (v,vi) has infinite or zero money to resolve the problem (Gadd, 2011, p. 18). The aim is that the practitioner will be forced to consider new situations, hopefully generating new solution ideas that may be used to aid in resolving the original problem. Size-Time-Cost Operator was selected as the ideation technique for this study, because it does not require specialised domain knowledge to utilise, and is suitable for students to learn in a short period of time (Belski, 2015).

Participants of the Study

Participants of the study were three tutorial classes of third year undergraduate engineering students. The tutorial classes were part of a course on engineering design. The experiment was conducted during a class which included discussion on the topic of creativity and problem-solving within the engineering discipline. As part of the class, students were involved in an ideation activity, which formed the basis for the experiment. This activity was not assessed as part of the course marks, but it was expected that students would attempt the activity as part of the practical material that was covered during the class. Before the activity began, students were made aware of the research project and advised that if they wished to participate, they would be able to anonymously submit their worksheets to the tutor (or online database for computer-based students) for analysis at the conclusion of the task. Participants of one tutorial class were used as a Control Group (CG) (N=23), while participants of the other two classes were allocated to either the pen-and-paper (PPG) (N=26) or the computer-based group (CBG) (N=30), depending on whether they had brought a computer to the class. A pre-experiment questionnaire, shown in Table 1, was utilised to establish whether the groups were equivalent, to allow for comparison between the groups.

Pre-Experiment Questionnaire

All participants were requested to complete a pre-experiment questionnaire. The questionnaire was comprised of questions that were utilised to understand whether the three groups possessed confidence levels similar baseline competencies in computing, problem-solving, and creativity skills, which may influence the outcomes of the experiment. Students were asked questions about their confidence in their computing ability, general problem-solving skill, problem-solving self-efficacy, fluency (i.e. number of ideas) during creative tasks, and regularity of creative thought using a 7-point Likert Scale questions (1-Strongly Disagree, 7-Strongly Agree). Results of the questionnaire may be observed in Table 1. Results of the Mann-Whitney U Test of significance showed that there were no statistical differences between any of the groups on any of the questions, suggesting the groups may be considered equivalent.

Table 1: Pre-Experiment Questionnaire. 7-point Likert (1-Strongly Disagree, 7-Strongly Agree)

Question	CG (N=23) M (SD)	PPG (N=26) M (SD)	CBG (N=30) M (SD)
1. I am very comfortable using computers for university related learning activities.	6.17 (1.20)	6.16 (1.11)	6.67 (0.76)
2. I am very good a problem solving.	4.96 (0.88)	5.24 (0.88)	5.37 (1.05)
3. I am certain that I am able to resolve any problem I will face.	4.78 (1.38)	5.04 (1.14)	5.20 (1.10)
4. I come up with novel ideas all the time.	4.56 (1.50)	4.68 (1.15)	4.77 (1.30)
5. I always have many concepts for how to resolve a problem I am facing.	5.00 (1.60)	5.04 (1.06)	5.07 (1.02)

Worksheet Templates

In order to compare performance of the three groups in an ideation activity and record questionnaire data, it was required that worksheet templates be provided for the participants of each group. Worksheet templates consisted of two sheets of paper in the case of CG and PPG, or two consecutive website pages for CBG. The first page of each template consisted of the pre-experiment questionnaire, and the second page included instructions and space to write during the ideation activity. The paper–based and computer-based templates for PPG and CBG were designed to be as similar as possible, so that any potential difference in performance between the groups may be attributed to the different platforms being utilised. The computer-based template for CBG allowed users to move between sequential web pages using buttons at the bottom of the pages. A button placed at the bottom of the second webpage allowed CBG to submit their ideas to an online database for later analysis. The second page of the worksheet template for CG was a blank and did not provide or suggest any guidance as to what may be done during the ideation activity.

The worksheet templates for PPG and CBG were required to be designed so that participants of these groups could implement the Size-Time-Cost Operator heuristic, without the need for prior instruction. This was done to match the conditions in the experiments by (Belski et al., 2015), where students were not provided with any prior instruction in how to utilise the provided material. The second page of the worksheet templates for PPG and CBG consisted of a set of six short sentences which encapsulate the six scenarios that form the basis of Size-Time-Cost Operator technique. A primary instruction was written at the top of the page: “Consider how you may resolve this problem if you could:”. This was followed by the following six conditions, each placed on a new line; (i) use (or make) something big, (ii) use (or make) something small, (iii) take a very long time, (iv) take only a very short time, (v) spend a very large amount of money, (vi) spend only a very small amount of money.

Experiment Procedure

The design of the experiment was based upon the experiment designs utilised in the studies by Belski et al. (2015) and Valentine et al. (2017), with some changes. Students were first provided with a brief overview of the activity. It was explained that participants would be provided with a worksheet for the activity, shown a creativity related problem, and be provided with 10 minutes to write down as many ideas to resolve the problem as they could. Participants of the study were then provided with a worksheet template applicable to the group they were in, and requested to complete the pre-experiment questionnaire.

Participants were then presented with the problem displayed in Figure 1. This scenario was adapted from a problem originally developed for a TRIZ creativity workshop at the University of Oxford (Gadd, 2011, p. 32). The problem presented the situation of a glass of water that has been placed on top of a table. The problem asked a person to think of as many ways as they can for removing the water from the glass, while ensuring not to move either the glass or the table. Students were provided with 10 minutes to generate ideas and write them down on the provided worksheet or webpage. At the tasks' conclusion, 23 and 26 worksheet templates were handed to the tutor from CG and PPG respectively, while a total of 30 entries from CBG were submitted to the database for analysis.

Figure 1: Problem that required students to generate solution ideas

Data Analysis

Submitted student worksheet templates or database entries were evaluated according to similar criteria followed in the study by Belski et al. (2015). Participants' performance was evaluated according to the distinct number of ideas that they had generated (idea fluency), and the diversity of the ideas that they had generated (idea flexibility). Idea fluency and flexibility are two common metrics that are used to assess creative performance (Cropley, 2000). Outlandish or unusual ideas (such as reversing gravity or using lasers) were not excluded, as long as the proposed solution may somehow resolve the presented problem. Ideas were considered distinct when the methods of removing water were not the same, even if they used similar physical concepts. For example, "use a straw" and "use a vacuum/syringe" were not distinct because they each utilise the concept of suction, while "use a vacuum" and "use compressed air to force out the water" were considered distinct as one idea uses suction while the other uses pressure. Analysis by the evaluators showed that overall, ideas proposed by students tended to align with one of 12 distinct concepts. These concepts including (but were not limited to): displacement, suction, pressure or force (e.g. compressed air), chemical change, evaporation or heating, freezing, absorption, electrolysis, cutting a hole in the base of the glass, syphoning, gravity (e.g. such as reversing gravity), and vibrating the water without moving the glass. To assess idea fluency, it is common that a set of categories are provided. Initially, it was expected that ideas would be allocated to the categories of Size, Time or Cost. However, during evaluation it became clear that these categories were not suitable, because it was often not clear which category (if any) students were considering when writing the idea. As categories utilised in the study by Belski et al. (2015) (the eight fields of MATCEMIB) were suitable, these categories were instead adopted for use in this study. This also allowed for a larger number of MATCEMIB categories to be used (8 instead of 3), allowing idea flexibility to more accurately reflect whether a student had generated ideas which utilised several distinct areas of knowledge.

Due to the subjective nature of the evaluation methodology, three assessors independently evaluated the idea fluency and flexibility for each submitted student worksheet template or database entry. To calculate fluency, the number of distinct ideas proposed by the student was established and recorded. Each idea was then allocated into one of the available categories. Once all ideas had been evaluated, the total number of categories used by the participant was established and recorded as the idea fluency. These evaluations were then checked for inter-rater reliability. The evaluations were shown to be reliable, with Cronbach's Alpha of 0.953 for idea fluency and 0.845 for flexibility. For further statistical analysis, each student's idea fluency and flexibility was then set as the average of the three assessor's evaluations (e.g. 5.33 if evaluations were 5, 5, and 6, respectively).

Results

Results showed that students had an average idea fluency of 5.03 (SD: 1.82), 5.04 (SD: 2.33) and 4.20 (SD: 1.96) for CG, PPG and CBG, respectively. Average idea flexibility was 3.10 (SD: 0.93), 2.99 (SD: 0.78) and 2.68 (SD: 0.90) for CG, PPG and CBG, respectively. The non-parametric Mann-Whitney U Test was used to test for statistical significance between groups, as the Shapiro-Wilk test of normality showed several distributions for idea fluency (CG and PPG) and idea flexibility (CG, PPG and CBG) were not normally distributed ($p < 0.05$). Outcomes showed there were no significant differences between any of the groups for either idea fluency or idea flexibility. Effect sizes between CG and PPG were negligible for idea fluency (Cohen's $d = 0.00$) and flexibility (Cohen's $d = 0.13$). Small effect sizes of a level to be considered educationally significant (Wolf, 1986), were established between PPG and CBG for idea fluency (Cohen's $d = 0.40$) and flexibility (Cohen's $d = 0.47$).

Due to the lack of significance in performance between groups, the groups may be combined to examine whether the metrics of idea fluency and idea flexibility were significantly correlated. Analysis showed a Pearson's correlation coefficient of 0.763, significant at the $p<0.001$ level. This demonstrated that student's ability to generate numerous ideas was linked to their ability to consider several fields of knowledge in the ideation process.

Discussion

The results of this study have demonstrated that exposing students to the Size-Time-Cost Operator heuristic does not necessarily lead to increased ideation performance relative to an equivalent control group. This outcome does not necessarily suggest that Size-Time-Cost Operator is unable to enhance ideation performance, but that it was unable to in this case. Student ideas generally aligned with one of approximately 12 overall distinct ideas, suggesting that there may only be a limited number of possible solutions to the chosen problem, which may influence the ability of Size-Time-Cost Operator to be effective. Results may differ if students were provided with a problem that can be considered more 'real-world'; this is a potential limitation of the study. This outcome suggests that the findings of Belski et al. (2015) are unlikely to be easily generalised to accurately include a large number of simple ideation heuristics, and that heuristics would each need to be individually evaluated in order to comprehend the effectiveness of each heuristic. Where educators seek to implement the teaching of ideation heuristics into curricula, it is important that the chosen ideation heuristics have been empirically demonstrated to enhance ideation performance over a control group, ideally on several independent occasions. The results suggest that students may be unable to effectively implement Size-Time-Cost Operator without prior instruction. Future research may aim to establish whether providing explicit prior instruction in the use of Size-Time-Cost Operator may lead to enhanced performance over a control group.

Considering the performance of PPG and CBG, although the number and diversity of ideas generated by PPG was higher than CBG, there were no statistical significances for either metric. Therefore when considering statistical significance, it has been shown that students were able to utilise a computer-based Size-Time-Cost Operator template at least as well as a pen-and-paper version, even if the technique itself did not enhance performance relative to a control group. These results do not oppose the results found by Valentine et al. (2017), where the group which utilised the pen-and-paper template generated a higher number of ideas than the computer-based group, but the difference was also statistically insignificant. However, it was also established that the effect sizes between PPG and CBG for idea fluency and flexibility were of an educationally significant level (Wolf, 1986). This potentially suggests that there may have been an unclear minor disadvantage to students who utilised a computer-based approach. The entire ideation phase of the experiment was spent on only one web page, so navigation of the website is unlikely to be an issue. Literature reviews comparing the experience of using paper-based and digital-based platforms have highlighted that reading from computer screens typically takes more cognitive effort and takes longer than reading on paper (Leeson, 2006; Millar & Schrier, 2015). However, the instructions provided to students were relatively minimal with only six short prompts provided, suggesting the cause for difference in performance may reside elsewhere.

The results of this study highlight an important point for educators; if computer-based ideation activities are to be provided for students, it is imperative not only to check if students fare equally well using computer as with pen-and-paper. It is important to ensure that the technique, and way it is being delivered, leads to a measured enhancement to performance.

The Fields of MATCEMIB and Size-Time-Cost Operator heuristics work in different ways, meaning the difference in performance between control groups and groups who implement these heuristics may relate to this. Problem-solving as a process is commonly modelled as a series of four steps including: understanding and framing the problem, devising a solution (ideation), implementing a solution, and evaluating and reflecting upon the implemented solution (Belski, 2002). The Fields of MATCEMIB heuristic works by directly providing a person with a set of suggested solution ideas (a Field of MATCEMIB or specific sub-concept). The aim is that each suggested solution idea may work as an analogy that triggers an idea from the person's long term memory, based upon something they may have seen or done in the past. The Fields of MATCEMIB heuristic is primarily associated with the second phase of problem solving; ideation. The Size-Time-Cost Operator works in a different manner, however. It first suggests a person to consider a set of extreme conditions (framing the problem), then think how the problem may be resolved under each of these extreme conditions (ideation), utilising ideas generated under the extreme conditions to try and resolve the original problem. In other words, the Size-Time-Cost Operator incorporates both the first and second stage of problem solving, not just the second stage as is the case with Fields of MATCEMIB. This may result in Size-Time-Cost Operator requiring more time and effort to be able to effectively generate ideas.

Conclusion

Recent research has demonstrated that exposing students to simple ideation heuristics (the Fields of MATCEMIB technique) was able to enhance their ideation performance relative to a control group (Belski et al., 2015), and that students were able to apply ideation heuristics effectively using either pen-and-paper or computer-based approach (Valentine et al., 2017). This study has investigated whether these research findings are repeatable when an alternative ideation heuristic is applied. Outcomes have demonstrated that exposing students to the Size-Time-Cost Operator technique did not lead to improved ideation performance relative to a control group. This contrasts with previous studies which demonstrate that using the Fields of MATCEMIB technique did improve performance. Results of this study also demonstrated that students were able to apply the Size-Time-Cost Operator technique effectively using either pen-and-paper or computer-based approach, aligning with the results of previous studies. The outcomes of this study suggest that not all well-established ideation techniques enhance idea generation performance. Where educators wish to expose students to simple ideation techniques, it is imperative not to assume that exposing students to any well-established ideation technique will always lead to enhanced performance. It is essential that the decision of what techniques are to be provided or taught is given as much consideration as the primary decision to teach ideation techniques in the first place. The decision of what techniques may be taught should ideally be based upon the results of empirical research that demonstrate the technique to be effective, in order to deliver the highest benefit to both the educator and students.

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Analysis of Usage for Two Digital Format Ideation Templates

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SESSION S2: EDUCATING THE EDISONS OF THE 21ST CENTURY

CONTEXT It has been reported that current teaching methods may lead to a significant decrease in students' creativity skills over the four years taken to complete an engineering degree. One reported approach of increasing creativity performance is exposure to suitable idea generation heuristics (Belski, Hourani, Valentine, & Belski, 2014). Research has demonstrated that students are able to apply suitable idea generation heuristics equally effectively using either a pen-and-paper or computer based approach, and that learning the heuristic using either platform leads to measurable enhancements in long-term performance (Valentine, Belski, & Hamilton, 2016). Website-based idea generation activities would requiring web browser software for usage, and the potential for enhanced interactivity, which can enhance engagement. But even simple websites generally take more time, effort and resources to make than other digital formats, such as Portable Document Format (PDF) files.

PURPOSE To establish whether students (in a *voluntary* setting) are more likely to use a website or PDF version of an idea generation template (similar in layout and content), when provided with the option to use either, or both. This will help to establish whether it is worthwhile to expend resources developing website-based versions in the interest of encouraging student usage of the learning resources in a voluntary setting, instead of PDF versions that generally take fewer resources to construct than website versions.

APPROACH Two idea generation heuristics were selected and learning resources were created for each heuristic; instructional video showing how to apply the heuristic, along with a website format template and similar PDF format template that each guided a person through the process of applying the heuristic. These resources were placed within a website that had been designed for the distribution of creativity related heuristics and techniques, which students were able to voluntarily make use of for self-directed study. A database was used to record the date and time each time either the website or PDF template for either heuristic was accessed over a period of twenty six weeks. Entries were collated into the appropriate week in which they occurred, and analysis was conducted to establish whether students were more likely to access one format of template than the other on average during a week.

RESULTS For the first heuristic, students accessed the website version at a ratio of 1.52 times more often than the comparable PDF version, and the difference was statistically significant. For the second heuristic, students accessed the website version at a ratio of 1.39 times more often than the PDF version, but the difference was not statistically significant.

CONCLUSIONS Overall, the findings may suggest that the uptake rate of digital-based idea generation activities in a *voluntary* usage setting may be higher if website versions of templates are provided rather than PDF versions, although this cannot be stated with certainty. Educators may therefore be inclined to dedicate resources to developing and hosting website versions, in the interest of maximising usage of provided learning resources by students. However, this study has not investigated whether usage of one digital format over the other lead to differences in apparent learning gains, which would also be important for educators to know before adopting such a decision.

KEYWORDS Ideation, digital format, usage statistics

Introduction

The need for creativity

The ability to demonstrate a creative and innovative demeanour is one of the expected traits of professional engineers (Engineers Australia, 2011). Research has demonstrated that fourth year undergraduate engineering students perceived themselves to be significantly more innovative than first year undergraduate engineering students (Davis & Amelink, 2016), suggesting that studying an engineering degree leads to an increase in students' confidence in their ability to be innovative and successfully build related skills. However, it is apparent that students' perceptions may not accurately reflect measured results. It has been reported that the problem-solving self-efficacy of students actually declines over the four years taken to complete an engineering degree (Steiner et al., 2011). Genco, Hölttä-Otto, and Seepersad (2012) investigated the innovative capabilities of first year and fourth year engineering students when solving a specified open-ended design problem. The overall findings suggested that fourth year students were less innovative than their first year counterparts. Other research has reported a concerning finding that the measured creativity levels of fourth year engineering students were significantly lower than that of their first year counterparts, although critical thinking was similar was measured to be similar (Sola, Hoekstra, Fiore, & McCauley, 2017), This may unfortunately suggest that some students' creativity actually decreased during the four years taken to complete an engineering degree. This is concerning as innovation requires the ability to generate ideas which can be considered as original or creative, that are also applicable in a practical manner to a real problem (Amabile, Conti, Coon, Lazenby, & Herron, 1996). When these outcomes are considered together, the conclusions are disconcerting. It is apparent that while students consider themselves as more innovative as a result of studying an engineering degree, research findings show that there is a disconnect between students' perspectives and their measured performance.

Inclusion of explicit (i.e. clearly stated in the learning outcomes) creativity related material within engineering curricula is relatively uncommon (Daly, Mosyjowski, & Seifert, 2014; Marquis, Radan, & Liu, 2017). It is asserted that where creativity related material is covered within curricula, it is typically covered through the introduction of idea generation (ideation) techniques or heuristics as part of a class on design (Genco et al., 2012). Finding ways to overcome the current lack of creativity related material is a challenge faced by many educators who deal with an already full curriculum.

Educators who have previously introduced courses that focus on the development of creativity and problem solving skills have reported benefits of enhanced creativity performance (Anderson, 2006; Chang, Chien, Yu, Chu, & Chen, 2016; Mahboub, Portillo, Liu, & Chandraratna, 2004). Considering creativity training on a larger scale, meta-reviews have concluded that creativity training (such as use of ideation techniques) is generally an effective means of enhancing the creativity of training participants, although it can depend on the context under which training is conducted (Scott, Leritz, & Mumford, 2004; Tsai, 2013).

An experiment conducted by Belski et al. (2014) investigated the influence of ideation techniques on first year engineering students in an ideation task of 15 minutes duration. It was found that exposing students to techniques resulted in significantly improved idea generation performance, leading to the suggestion that short, self-contained ideation activities may be included in courses throughout an engineering degree as a means of enhancing the creativity of students. Follow up research concluded that providing creativity training on the application of an ideation heuristic via a 10 minute instructional video and subsequent involvement in a 15 minute ideation task, lead to a measurable enhancement to participants' ideation performance even after a period of three months (Valentine et al., 2016). Furthermore, it was established that students were able to effectively perform in the initial ideation task using either a pen-and-paper or computer-based template, and that the platform which students used during the initial task had no influence on the long-term performance of participants. It was therefore concluded that web-based ideation tools may be a suitable means of providing students with opportunities to enhance their creativity skills, while having the benefit that students may access and make use of them at any time, and that educators may provide this access without requiring the use of dedicated class time.

Digital-based ideation activities: in which format?

A significant dilemma to this conclusion is that websites generally take significant time, effort, and resources to develop and host. This raises the question of whether it is worthwhile to expend resources to develop web-based tools which guide a user through the process of applying a specified ideation technique, when students may instead make use of a digital format template which takes fewer resources to develop, such as PDF (Portable Document Format). Students may potentially make higher usage of digital-based ideation activities if they are website-based, though this is unclear. However, this would lead to a disadvantageous situation for educators who would need to spend more time, effort and resources to construct the required learning materials.

There is a current lack of studies in the available literature which have attempted to investigate the usage rates or preferences of students when provided with two digital format ideation template alternatives. Many studies that compare the actual usage (or access) rates of two formats that present identical content using the same layout, are library based studies which have investigated the usage rates of print books compared to their equivalent same-title electronic-book formats (Christianson & Aucoin, 2005; Morgan, 2010; Ramirez & Tabacaru, 2015; Taylor, 2013). Literature comparing digital-based formats is relatively limited in the literature. Pettifer et al. (2011) compared the theoretical advantage and disadvantage perspectives of representing academic articles in different digital formats such as PDF and websites, finding that each format has different benefits or drawbacks depending on the context, such as storage, human tasks (such as reading) or machine task (such as searching for text). Other literature reports findings of participants' usage preferences. A survey of 281 academics conducted by Elsevier investigated which format academics preferred for research related purposes, establishing that academics considered PDF to be preferable for in-depth reading, but website format to be preferable for searching for information due to convenience (Aalbersberg, 2013). A related study of 184 undergraduate students conducted by Schierhorn, Wearden, Schierhorn, Tabar, and Andrews (1999) found that when provided with the choice of reading a traditional print newspaper or a digital newspaper using either website or Portable Document Viewer (PDV) formats, participants demonstrated an overall statistically significant ($p < 0.05$) preference for digital items in the PDV, rather than website format. Although these studies provide insightful research findings, it is difficult to accurately infer which format of ideation templates students may be more likely to utilise or preference.

The aim of this study is to investigate students' access rates of two digital-based ideation templates that are presented in different formats (PDF and website), when presented with the *voluntary* opportunity to utilise either (or both) for use in self-directed study. Understanding which format of digital-based template is more heavily accessed will help educators to understand whether it is worth investing time, effort and resources in the development of website-based ideation templates in this context, or if it is suitable to provide templates that take fewer resources to develop and host, such as PDF.

Methodology

Ideation Techniques

To compare usage rates of two digital format ideation templates, appropriate templates first needed to be created. For this, selection of an appropriate ideation technique upon which to base the templates was required. The website- and PDF-based templates were required to be designed in order to guide a person through applying the technique with minimal external instruction. To check for repeatability, it was selected that two ideation techniques would be utilised and a website- and PDF-based template would be created for each.

The Fields of MATCEMIB (Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular, Biological) is a TRIZ (Russian: teoriya resheniya izobretatelskikh zadach, English: theory of inventive problem solving) based problem-solving methodology that is primarily designed to find solution ideas to problems of a technical nature. The technique has repeatedly been shown to enhance the ideation performance of engineering students relative to a control group provided with no external guidance (Belski et al., 2015). Moreover, it has been demonstrated that exposure to the Fields of MATCEMIB technique and subsequent engagement in an ideation task of 15 minutes duration lead to measurable improvement in ideation performance even after a period of three months (Valentine et al., 2016). Therefore, this technique was selected as one of the two ideation techniques for which digital-based templates would be created.

The Fields of MATCEMIB technique requires relevant domain knowledge to apply the technique most effectively. Therefore, it was nominated that the second technique be more widely applicable to a wider range of problem types, not take much time to learn, and not require specific domain knowledge. Size-Time-Cost Operator is a TRIZ ideation technique (Gadd, 2011, p. 18) which meets these criteria (Belski, 2015), and was accordingly chosen as the second technique for which digital-based templates would be created.

Digital-Based Templates

PDF templates were first created for both of the two ideation techniques. The templates consisted of several steps appropriate for the ideation technique. For each technique, the template guided the user to first set up the scenario of interest in the manner appropriate for the technique. Once all necessary information was provided, the templates guided the user to generate ideas to resolve the problem. Both the Fields of MATCEMIB and Size-Time-Cost Operator techniques do this by systematically repetitive means. Each technique forces the user to focus on and consider one distinct concept at a time, which has been asserted to improve ideation performance as it means that a person is less likely to try and simultaneously consider several potential solution ideas (Belski & Belski, 2008). A separate prompt and space to write ideas was provided for each of the distinct concepts a person must consider when implementing each technique. The Fields of MATCEMIB asks a person to consider eight distinct concepts for generating ideas (the fields of Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular, Biological) (Belski, 2007), therefore these templates included eight applicable prompts and space to write ideas underneath, displayed on the template one after another. Likewise, the Size-Time-Cost Operator asks a person to consider six distinct scenario for generating ideas (when available Size, Time, and Cost are zero or infinite) (Gadd, 2011, p. 18) and the applicable prompts were presented sequentially and with space to write ideas underneath.

Once the PDF templates were created, a website-based version of each was created. The website versions were designed to have a similar layout to the PDF versions. Each website template contained several webpages which the user was able to sequentially navigate through, and logically segmented the information contained within the PDF versions into appropriate webpages. Alongside the digital-based templates, an instructional video of approximately 10 minutes duration that explained to students how the appropriate heuristic, was created for each of the two heuristics.

An index webpage was then created for each heuristic. Each index webpage contained links to the three resources applicable for each heuristic; the instructional video, the PDF template, and the website template. Both of the index webpages, videos, PDF templates and website templates were then placed within a repository website that had been specifically designed for distribution of creativity related heuristics and techniques, that students would be able to voluntarily make use of in self-directed study in order to enhance their creativity when solving open-ended or ill-defined problems that formed part of their coursework.

Data Collection

In order to assess the rate at which students accessed one type of digital-based template compared to the other, a database was set up to record an entry every time a student independently accessed the website or PDF template for either heuristic. Each entry recorded the date and time of the resource access.

At the beginning of a university semester, the repository was promoted to engineering students of some Australian and New Zealand universities through the Engineers Without Borders association and the Golden Key International Honour Society. Engineering educators at these universities, especially those teaching courses on engineering design or participating in the Engineers Without Borders Challenge, were requested to inform their students regarding the availability of the repository and briefly discuss potential benefits of utilising creativity heuristics within their projects. Due to the nature of promotion of the repository and voluntary usage of its’ contents by educators and students, it was not possible to fully control the extent to which educators promoted the repository within their classes, or accurately predict exactly how many students the repository was promoted to. This is a limitation of the study, and results may therefore be different if students were required to use the repository for their projects. Educators and students were again provided with the information after a period of eight weeks. The creativity heuristic resources were made available to students to voluntarily use in self-directed study for a period of 26 weeks, and the access rate of each template style for both heuristics was recorded over this period of time.

Data Analysis

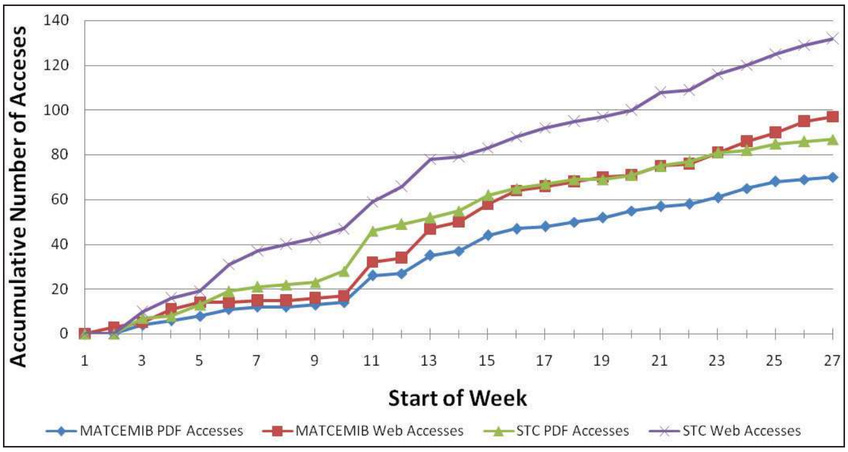

Figure 1: Accumulative of Times Each Resource Accessed over 26 week period

After the period of 26 weeks had concluded, the data was analysed. The data was evaluated and categorised according the week in which the database entry had been created. This allowed observation of how many students had accessed each template during each of the 26 available weeks. The accumulated number of times that each template had been accessed at the start of each week can be observed in Figure 1. Analysis showed that there were a relatively high number of template accesses in week 10, compared to other weeks. Each resource type was accessed at least 12 times during week 10. The Fields of MATCEMIB web tool was accessed 13 times during week 12, and the Size-Time-Cost Operator web tool was accessed 10, 12 and 12 times in Weeks 2, 5 and 12, respectively. These relatively high usage values may reflect weeks where academics may have informed students about the availabilities of the self-directed learning resources, creating a higher uptake by students in their respective courses.

Results

Analysis showed that students used the Fields of MATCEMIB PDF template a total of 70 times during the 26 weeks (M: 2.69, SD: 2.66), while they used the Fields of MATCEMIB website template a total of 97 times (M: 3.73, SD: 3.64); a ratio of 1.39 website utilisations for each PDF utilisation. Students used the Size-Time-Cost Operator website a total of 87 times during the 26 weeks (M: 3.35, SD: 3.58), and used the PDF template 132 times (M: 5.08, SD: 3.38); a ratio of 1.52 website utilisations for each PDF utilisation. The access data for all four templates were not normally distributed according to the results of the Shapiro-Wilk test of normality; therefore the non-parametric Mann-Whitney U Test was used to check for statistical significance between groups. Results of the Mann-Whitney U Test showed that there was statistical significance between usage rates of the Size-Time-Cost Operator template formats ($Z=-2.318$, $p=0.020$), but not between usage rates of the Fields of MATCEMIB template formats.

It can be observed in that the standard deviation for the usage rate of several templates was quite large compared to the mean. This is likely caused by the unusually high access rates of templates during certain weeks, as previously discussed. It was therefore decided to re-conduct analysis with outliers removed to see if this resulted in any change to the statistical significances. Removal of outliers resulted in the Size-Time-Cost Operator website version being accessed a total of 43 times (M: 1.87, SD: 1.14), and the PDF version a total of 69 times (M: 2.88, SD: 2.09), respectively. The Fields of MATCEMIB website version was accessed a total of 69 times (M: 2.76, SD: 2.01), and the PDF version a total of 132 times (M: 5.08, SD: 3.38), respectively. Evaluation showed that after removing appropriate outlier values from each group, statistical significance between Size-Time-Cost Operator template access rates remained, while the lack of statistical significance between Fields of MATCEMIB template access rates also remained. In other words, removing outliers from each group did not change the results.

Discussion

The results of this study have demonstrated that when provided with the opportunity to make use of either website- or PDF-based ideation templates that are equivalent in content and similar in design layout in a *voluntary* manner, students may be more likely to access the website-based version, although this cannot be stated with certainty. It was evaluated that students accessed the Size-Time-Cost Operator website ideation template significantly more often on average per week than the PDF template, with the website version being used at a rate of 1.52 times that of the PDF version. However, this finding was not repeatable for template access rates for the Fields of MATCEMIB heuristic. Although students accessed the Fields of MATCEMIB website template at a rate of 1.39 times that of the PDF template, the difference in mean number of weekly accesses by students was statistically insignificant.

It is difficult to directly compare the findings of this study to that of existing literature, as existing studies either compare actual usage rates of print and equivalent electronic book formats, or compare the preferences people have between two digital-based formats that are being used in very different contexts to this study (such as academic research or newspaper reading). Previous research has found that people significantly preferred to read and access newspapers using a Portable Document Viewer format over a website format (Schierhorn et al., 1999), while this study found that participants accessed the website version at a higher rate. As the participants of this study and the study by Schierhorn et al. (1999) were both of similar age groups, this suggests that the usage rates or preferences that people are likely to show between two digital-based formats, may be highly dependent on the context or activity.

These outcomes suggest that there may be merit in the notion that educators may seek to develop digital-based ideation templates that are website based for use in *voluntary* settings. Although the mean weekly usage rate of Fields of MATCEMIB web template was not significantly higher than the PDF template, the usage ratio suggests students still suggests a slight preference for the website templates. Educators may consider how these findings may assist them to engage students with ideation style learning activities in a voluntary context. As students have already demonstrated a potential slight preference for website based ideation templates in a voluntary setting, educators may use this to their advantage in the interest of encouraging higher usage of the learning resources. Software which has increased levels of interactivity is likely to encourage students to use the software, especially where the software can be considered fun to use (Cavallucci & Oget, 2013). It may be reasoned that if educators were to develop website-based ideation activities with high levels of appropriate interactive features (as opposed to being akin to a static worksheet), and make students aware of these interactive features, students may be further inclined to make use of ideation learning materials that are provided for them to use in a voluntary setting. In turn, this may help to enhance their creativity skills and help to at least in part overcome the decline in creativity and innovation skills that has been reported to occur over the four years taken to study an engineering degree (Genco et al., 2012; Sola et al., 2017).

It is important to consider the limitations of this study. It is required to emphasise that this study did not aim to address whether students may make more effective use of ideation templates when they are in PDF or website format, but aimed to provide a foundation for understanding whether students show a preference for one format or the other in a *voluntary* setting. While it is reasonable to assert that students may simply use the format that is provided if no choice it offered, and that there may not be reason for educators to consider website format over PDF format, it is important to reflect on the voluntary usage of learning resources that aimed to be addressed in this study. It is likely that students will make use of a voluntary learning resource at a higher rate, when it suits their preference of format. Students may show a different preference of format if they are *required* to use the learning resource. The consideration of whether one format may be more beneficial to students than the other in a voluntary setting, and whether students may prefer one format over the other in a setting where they are required to use the resources was outside the scope of this study and is a possible direction for future research. Future research may investigate whether these findings are repeatable in a setting where students are expected to use the resources. Qualitative measures may also provide insight into the potential benefits or disadvantages of using templates, or engaging in activities, that use one digital format or another.

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Australian electrical engineering curricula and development of creativity skills: How do we rate?

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SESSION S2: EDUCATING THE EDISONS OF THE 21ST CENTURY

CONTEXT Engineering employers consider the ability to innovate and be creative as useful employment skills. Unfortunately, it has been reported that the creativity skill of some undergraduate engineering students decreases throughout a degree, and that many students are likely to suffer design fixation and stay with the first idea that comes to mind during idea generation, inhibiting their ability to generate creative concepts and develop their abilities. Numerous educators advocate for increased focus on creativity material within engineering curricula; one demonstrated method of enhancing these skills is to directly introduce students to creative problem-solving approaches. This raises the question to what extent existing engineering programs include creativity-related content that aims to overcome these issues, as currently this is not quantifiably understood for Australian engineering programs.

PURPOSE To establish the extent to which students are exposed to creativity-related concepts and taught creativity-related heuristics in Australian undergraduate tertiary engineering programs, in order to comprehend whether Australian engineering programs actively assist in providing students with course material that enhances their ability to apply creative approaches and develop alternative solutions to a problem.

APPROACH A list of Australian Qualification Framework Level 8 engineering single degrees accredited by Engineers Australia (offered during 2017) with “electrical” in the degree title and which had available program handbooks was compiled, resulting in set of 34 distinct degree programs offered at 25 tertiary institutions. A list of all the core/compulsory courses that a student must complete as part of each program was complied. Each course outline/handbook (including course description, learning outcomes etc.) was then consulted to determine whether the course explicitly (i) discussed the concept of creativity and/or innovation within the field of engineering (ii) included material on the application of creative approaches to aid in developing alternative problem solutions. Courses were evaluated to either meet each of the criteria or not, based upon information in the course outline.

RESULTS Of the 34 programs and 919 core courses evaluated, a total of 20 courses at 17 institutions included explicit demonstration or explanation of the concept of creativity and/or innovation within the field of engineering. No programs were evaluated to include courses containing material that explicitly exposed students to, or required of application of, creativity heuristics or techniques. It was also established that very few courses required students to specifically demonstrate creativity and innovation in their stated learning outcomes.

CONCLUSIONS Results show an overall lack of curricula material aimed at exposing and teaching creativity skills within Australian undergraduate electrical engineering programs, as well as a widespread lack of curricula material which explicitly discusses the concepts of creativity and innovation within the field of engineering. In order for tertiary institutions to produce students who are able to be more creative and overcome inhibition to develop alternative concepts, it is recommended that programs adapt to incorporate learning outcomes that are specifically aimed at enhancing students’ creative thinking skills.

KEYWORDS Creativity, ideation, course outlines, learning outcomes

Introduction

The ability to show a “creative, innovative and proactive demeanour” is one of the expected competencies of an accredited professional engineer within Australia (Engineers Australia, 2011). Studies demonstrate that engineering employers place value on the ability of their employees to effectively demonstrate utilisation of skills relevant to this area (Male, Bush, & Chapman, 2010; Wickramasinghe & Perera, 2010).

Creativity is important to engineering, because it directly relates to a core component of problem-solving. Although there are numerous models that describe stages which comprise the problem-solving process (Belski, 2002), one stage is common amongst these models: the stage of generating solutions to the problem that is being faced. This stage is often referred to as the idea generation stage. Unfortunately, idea generation is a stage of problem-solving that engineering students tend to do poorly. Students can become easily hampered by design fixation and find it hard to develop alternative solution ideas (Condoor, Shankar, Brock, Burger, & Jansson, 1992; Kershaw, Holtta-Otto, & Lee, 2011; Samuel & Jablokow, 2010). Many students are likely to fixate on the first idea which comes to mind and find it hard to change their focus (Kershaw et al., 2011; Samuel & Jablokow, 2010), a situation made worse by spending insufficient time generating alternative solution ideas (Samuel & Jablokow, 2010). These traits can severely limit students’ ability to be creative. This does not suggest that students do not see the value in creativity-related material: the inclusion of creativity within engineering education is something which has shown to be positively valued by engineering students of all year levels (Waller, 2016).

It has been suggested by Daly, Mosyjowski, and Seifert (2014) that inclusion of creativity-related material within engineering programs is relatively rare. Numerous educators consider there is a need for increased focus on creativity and innovation material within engineering curricula in tertiary institutions (Atwood & Pretz, 2016; Cropley, 2015; Daly et al., 2014; Samuel & Jablokow, 2010; Tekic, Tekic, & Todorovic, 2015), as many engineering programs lack such content. Research has also concluded that engineering students who initially demonstrate a higher self-confidence in their creativity skills are less likely to complete an engineering degree, and are more likely to drop out (Atwood & Pretz, 2016). It may be considered that some students with higher levels of creative self-confidence may feel as though they are unable to effectively express and further enhance their creativity throughout an engineering degree. A recent study reported results that may support this notion; while the critical thinking capabilities of senior and freshman engineering students were found to be relatively similar, senior students were evaluated to overall be significantly less creative than their freshman counterparts (Sola, Hoekstra, Fiore, & McCauley, 2017).

These findings raise the consideration to what extent do Australian engineering programs currently engage students with creativity-related material. Existing research in this area primarily focuses on programs outside of Australia, and is often limited to the analysis of programs at one institution, such as studies conducted by Daly et al. (2014) and Marquis, Radan, and Liu (2017). This leads to the further consideration of how Australian engineering programs may further work to ensure that the creativity-related competencies set out by Engineers Australia (2011) are effectively enhanced during a four-year engineering degree. Currently it is not quantifiably understood to what extent Australian engineering programs engage students with creativity-related material.

Methodology

Assessing whether courses teach “creativity”

Attempting to determine if an engineering program may teach anything related to creativity, is clearly too vague without further clarification. For example, some educators may consider that in order to complete certain capstone or engineering design projects, it is *inferred* or *implied* that creativity must be shown, while other educators may advocate that creativity must be explicitly included within the learning outcomes of a course. As the role of an educator should ideally be to attempt to enhance the skills of the entire cohort where possible, it is important to not only consider whether engineering curricula cater for students who can effectively demonstrate creative skills, but aim to enhance the skills of those who struggle to do so. In order to evaluate how creativity is currently taught and may therefore be improved, it is required that meaningful and measurable criteria are utilised. This study will focus on evaluating whether courses *explicitly* cover selected material related to creativity.

One potential measure was evaluation of whether engineering programs include material which sufficiently explains the importance and concept of creativity within the domain of engineering. Inclusion of such material is likely to provide students with a more concrete understanding of how creativity and innovation relate to their chosen field of study, potentially resulting in students becoming more aware and engaged with the area of creativity and innovation. Explicit knowledge that engineering employers value these skills may also motivate students to seek out methods of enhancing their creativity.

It has been asserted by Genco, Hölttä-Otto, and Seepersad (2012) that “creativity, as part of the engineering design curriculum, is typically taught by introducing a set of ideation methods as part of a junior- or senior-level, or occasionally a freshman-level design class”. This assertion is reflected by the findings of a study which discovered that faculty members from the field of engineering rated the generation of multiple ideas or outcomes as being the most important factor that was related to creativity (Marquis & Vajoczki, 2012). A second potential measure was therefore to evaluate whether engineering programs included material which actively demonstrates to students that it is possible to enhance their creativity skills by implementing structured processes that are designed for this purpose (i.e. creativity training).

Creativity-related heuristics and techniques

Creativity-related heuristics or techniques in this study refer to any structured processes that are designed to enhance a person’s creativity when used, often by leading to the creation of additional solution ideas that may not otherwise have been thought of by the person. The ability to generate alternative ideas and consider ideas from various fields of knowledge or categories, are often used as core metrics to assess creativity (Cropley, 2000). Such creativity-related heuristics or techniques may include (but are not limited to) Brainstorming, Mind mapping, 6-3-5, C-sketch, Six Thinking Hats and Random Word by Edward de Bono (De Bono, 1988) and TRIZ (Russian: teoriya resheniya izobretatelskikh zadach, English: theory of inventive problem solving) methodologies.

Compiling details of Australian electrical engineering programs

This study is limited to the consideration of programs that adhere to the requirements of Australian Qualifications Framework (AQF) Level 8, and only covers the sub-discipline of electrical engineering, due to resource and scope constraints. AQF level 8 corresponds to a bachelor honours degree program (Australian Qualifications Framework Council, 2013). For Australian engineering programs, this comprises undergraduate engineering programs completed over four years full-time.

In order to evaluate whether Australian electrical engineering programs expose students to creativity-related material, a list of applicable programs was required. A list of AQF Level 8 engineering degrees accredited by Engineers Australia (2017) with the words “electrical” and “engineering” within the degree title was compiled. Double or dual degree programs were excluded, only single degree programs were considered for analysis. This list was then reduced to include all programs for which an applicable program structure was publicly accessible from the host institution’s website, resulting in a set of 34 distinct degree programs offered at 25 tertiary institutions. Distinct refers to the fact that each program has a unique title; several programs at the same institution may include the same course.

For each program, a list of all the core or compulsory courses that a student must complete in order to graduate from the program was compiled. All forms of electives courses were excluded from consideration as the aim was to establish whether a program *ensured* that a student was exposed to creativity-related course material, not only whether the program provided students with the *opportunity* to be exposed to creativity-related course material. Ideally, if engineering educators wish to enhance the creativity-related knowledge and skills of students, such material should be incorporated in a way that it clearly forms part of the intended learning outcomes for at least one core course within the program.

Criteria for analysing course outlines

For each of the 34 unique degree programs, the course outline or handbook (including course description, learning and teaching activities, expected deliverables, learning outcomes etc.) of every compulsory course was then accessed by means of the applicable institution's website. The information contained within the course outline was then consulted to establish whether it may be argued that the course was likely to meet one or both of two selected criteria. Analysis of online publicly available course outlines has previously been used by Marquis et al. (2017) to assess how creativity instruction varied across disciplines at a tertiary institution, although the process of how course outlines were analysed was different. Both criteria were considered and analysed independently, so a course was able to meet the first criterion but not the second, or vice-versa.

The first criterion was whether the course *explicitly* introduced the concept of creativity and/or innovation within the field of engineering. This included, but was not limited to:

- Description of how creativity, innovation or ideation may be a part of the problem solving or engineering design process. For example, demonstrating a model of the problem-solving process and highlighting that "developing several alternative solution ideas" (or similar wording) is often modelled as the second of four primary stages.
- Providing information that allows students to understand that there are methods, heuristics or techniques designed to enhance creativity (such as mentioning that Brainstorming, TRIZ, 6-3-5 or C-sketch techniques exist), but students are not actually shown the detailed process of how to apply such processes.
- Case studies or analysis of people that have worked in engineering-related fields and are considered to have been creative. For example, analysis of what made the person "creative" or "innovative", and how the student may learn from this.

The second criterion regarded whether the course *explicitly* included material on the utilisation or application of creativity-related heuristics and techniques. This included, but was not limited to:

- Students are shown the detailed process of applying specific creativity or ideation-related heuristics or techniques by an educator (such as Brainstorming, TRIZ, 6-3-5 or C-sketch techniques), but may not be required to apply the technique themselves.
- Students are expected to apply a nominated creativity-related heuristic or technique to a problem, in an active learning manner (such as Brainstorming, TRIZ, 6-3-5 or C-sketch techniques). It did not matter whether students' work was assessed or not.

Courses were evaluated to either meet each criterion or not, based upon information in the course outline on the applicable institution's website. Courses were evaluated to not meet criterion where the course outline only claimed to meet section 3.3 ("Creative, innovative and pro-active demeanour") of the Stage 1 competencies set out by Engineers Australia (2011). It was required that the course outline made clear how this was actually achieved through course content, and so for the purposes of this study, met the criterion.

Procedure for analysing course outlines (Data analysis)

To analyse each course, an independent spreadsheet was created for each engineering program. The list of compulsory courses within each engineering program was then listed on the applicable spreadsheet. Analysis was conducted in two stages. The first stage aimed to reduce the list of courses in each program to those which may reasonably be considered to meet either of the two criteria based upon text within the course outline, even if the link may be rather vague. This included (but was not limited to) mentioning words like “thinking skills”, “creativity” and “innovation” or any derivation (such “creative” or “innovate”). The second stage introduced a form of inter-rater reliability, by reducing the list of courses to those which were more likely to be widely accepted as meeting one or both of the two criteria.

During the first stage, one assessor evaluated the content contained within the course outline or handbook for each compulsory unit within each engineering program. This resulted in the analysis of 919 courses from 34 independent engineering programs. In this stage, the assessor evaluated whether it was possible for each course outline to reasonably be linked to meet either the first and second criterion. As previously described, where it was established that a vague link may be made, the course was not excluded. Courses were included where they provided details that were somewhat analogous to the example situations previously mentioned, or included any information which may reasonable be interpreted as somewhat covering the concept of creativity in engineering, or use of application of creativity-related processes. This resulted in 877 of the original 919 courses being excluded during the first stage, with 42 unique courses being considered to potentially fulfil either one or both of the two evaluation criteria.During the second stage of analysis, three different assessors that were not part of the first stage of course evaluations, were provided with a list of all courses that were not selected for exclusion during the first stage. Each assessor then independently reviewed each course outline, and evaluated whether the course independently met either one or both of the two provided criteria. Results of these evaluations were then checked for agreement. For instances where at least two of the three assessors evaluated that a course met a certain criterion, the course was deemed to have met that criterion and was recorded. Otherwise, the course was recorded as not meeting the criterion.

Results

Results of the second stage of analysis showed that out of the 34 unique engineering programs assessed, there were a total of 17 programs which included at least one course which met the first criterion and discussed the concept of creativity and/or innovation within the field of engineering. Considering all of the 919 compulsory courses that were assessed, it was established that 20 courses were deemed to meet the first criterion and discussed the concept of creativity and/or innovation within the field of engineering.

Of the 34 unique engineering programs that were assessed, it was established that no programs included courses that met the second criterion and included material on the application of creativity-related heuristics and techniques. Although some assessors evaluated some courses as meeting criterion 2, there was never an agreement between assessors that any course met the criterion.

Discussion

Reflecting on the results of this study, it was found that only half of Australian undergraduate electrical engineering programs include content which explicitly engage students with actively and purposefully learning how creativity relates to their domain of study. Where such material is included, it is usually restricted to one course within the program. Additionally, very few programs (if any) were found to include discussion on how students may work to improve their own creativity skills. Inclusion of course content which aims to explicitly expose students to creativity-related material appears to be relatively rare, suggesting that students are likely to have few opportunities to learn about the topic of creativity during the four years taken to complete an engineering degree. At a minimum, these outcomes demonstrate that it is rare for courses to incorporate learning outcomes that are explicitly related to creativity. These outcomes are similar to those of Marquis et al. (2017), who evaluated that only 1% of the total 149 engineering course outlines at a Canadian tertiary institution contained explicit references to creativity. Overall, the outcomes of this study confirm the conclusions of Daly et al. (2014), that inclusion of creativity-related material is relatively rare within engineering programs. The assertion of Genco et al. (2012) that creativity in the engineering curriculum is usually taught by introduction of ideation techniques, also does not appear to be an accurate depiction of engineering curricula within Australia.

The findings of this study suggest that creativity is overall given a low priority within existing engineering curricula. Educators may assert that students are implicitly exposed to the topic of creativity and sufficiently build upon related skills through situations which allow students more freedom of design, such as capstone or engineering design projects. However, where one of the intentions of a course is to develop creativity-related knowledge or skills, it should ideally form one of the clear learning outcomes for that course. A core issue exists within a conclusion that creativity is sufficiently enhanced through current teaching methods Research has demonstrated that current. methods of exposing students to creativity-related material and enhancing creativity-related skills, does not necessarily lead to an increase in creativity and innovation related-traits over a four year engineering degree, in fact, significant decreases were reported (Genco et al., 2012; Sola et al., 2017).

The startling outcomes of this study have shown findings important both to engineering education, and engineering industry. Studies demonstrate employers place high value on creativity skills (Male et al., 2010; Wickramasinghe & Perera, 2010). In addition, recent reports have highlighted the need for creativity and innovation within Australian businesses, in order to be able to perform effectively and compete within the Australian economy (Deloitte, 2017; Department of Employment, 2016). It is clear that engineering programs may not consistently produce graduates who effectively meet this industry requirement. Adapting engineering curricula should be of utmost importance to curricula designers, to ensure that Australia will be able to produce engineering graduates who are able to meet this challenge.

There is a question of what may be done to try and address these findings. One previous suggestion is the introduction of short activities that are designed to expose students to specified creativity-related heuristics, as such activities may be accommodated into existing curricula restraints by being included in various courses throughout an engineering degree (Belski, Hourani, Valentine, & Belski, 2014). It has been demonstrated that introducing students to such heuristics can have real benefits to their creative performance, even after a period of three months (Valentine, Belski, & Hamilton, 2016). Such measures may allow educators to provide students with increased opportunities to work on enhancing their creativity skills throughout studying an engineering degree. If engineering programs are adapted to ensure that some courses provide students with an introduction to the topic of creativity in engineering, this may allow students to become more creative, innovative, and better meet the changing requirements of engineering industry. Additionally, it recommended that where courses intend to cover any creativity related topics, even if it is not a primary learning outcome of the course, that these topics are clearly outlined in the course guide of handbook. This will help comprehension of how engineering programs address the “creative, innovative and proactive demeanour” capability described by Engineers Australia (2011).

It is important to consider the limitations of this study. It is possible that the results presented in this study may not be able to generalised to reflect the entirely of engineering curricula within Australia. This study has been limited to undergraduate engineering courses in the electrical discipline. Programs of other engineering disciplines or postgraduate level may explicitly include creativity-related material at a higher rate. Engineering programs within Australia may also be different to other comparable countries. While outside the scope of this study, future research may aim to address these points by investigating whether the findings of this study are similar to that of other engineering disciplines within Australia, or how Australian electrical engineering programs compare to that of other counties. Ideally, two or more assessors may independently carry out the first stage of course outline or handbook analysis, and then compare which courses were commonly evaluated to match the criterion or not. This may lead to more reliable results. A large number of courses were excluded during the first stage of data analysis. However, it is imperative to consider the construction of engineering programs. Many programs consist primarily of courses which focus on the development and application of domain specific knowledge that is required in order to be able to work as an engineer; the majority of such courses focus on developing convergent-based problem-solving skills. As is reasonably anticipated, the vast majority of these courses do not contain material which is expected to relate to creativity.

A limitation of using course outlines to assess whether courses meet the two criteria is that the level of detail provided by tertiary institutions is not standardised and is subjective. Some institutions have shorter descriptions and less information, while others have longer descriptions with more detailed information which make it easier to assess if the course fulfils the criterion. It is unreasonable to expect that all course outlines will detail all material that is covered throughout the course. However, it must be noted that course outlines at a minimum are expected to describe the core details of what is covered or taught in the course. It can therefore be reasonably asserted that if a course outline does not contain details which explicitly relate to creativity, it is clear that the development of creativity skills is not likely to be a primary learning outcome for the course. Nevertheless, it is possible that certain courses may include material which meets either or both of the two criteria, but this information was not clearly included in the course outline and was therefore excluded.

Conclusion

Recent research has reported that the creativity skills of engineering students do not necessarily increase during the four years taken to study an engineering degree, despite that creativity is a skill industry seeks. This study investigated the extent to which Australian electrical engineering programs engage students with creativity-related material, to understand whether sufficient actions are currently being taken to address this concerning issue. Specifically, it was investigated whether programs explicitly included material which discussed the topic of creativity within the field of engineering, and explicitly included material on the utilisation or application of creativity-related heuristics or techniques. Course outlines for 919 core courses from 34 distinct electrical engineering programs (offered by 25 tertiary institutions) accredited by Engineers Australia, were evaluated. It was found that 20 courses (from 17 programs) offered at 17 institutions explicitly included material which discussed the topic of creativity in engineering, while not one of the 919 core courses evaluated included material on the utilisation or application of creativity-related heuristics or techniques. These findings confirm recent assertions of educators who note that creativity is not widely taught, and is generally given a low priority in engineering education. These outcomes demonstrate that teaching of creativity-related skills at many tertiary institutions is likely done through implicit methods such as completion of capstone projects rather than explicit methods, and may not provide many students with sufficient instruction to effectively build on their skills. In order for engineering graduates to better meet the challenges faced by industry, educators may need to re-assess how creativity is currently taught and whether students are currently provided with sufficient exposure and instruction in the use of creativity.

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The Correlation between Practice Time and Student Improvement in Mathematics

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Structured Abstract

Context

As all engineers are fully aware the mathematics in engineering courses is used not only for calculating solutions to problems, but for many other functions. Mathematics is a language for understanding, a language for teaching, and most importantly it is a language that makes self-study and continuing professional development easier. It is therefore necessary that engineers know not only various mathematical procedures but also understand them and are fluid in them, i.e. can use them easily and almost without thinking. In order to get this fluidity, it is necessary that students are exposed to two processes when learning mathematics:

- The student must be given lectures which explain the important concepts in the relevant mathematics clearly. Further, these lectures must be given by a lecturer that understands the structure of the particular mathematical topic being covered and who understands the links between the topics being covered and the other mathematical topics that engineers need to know.
- The students need to undertake *directed* practice with relevant *feedback* in the mathematics that they need to know.

Purpose

The hypothesis of this paper is that in order to become fluid in mathematics the student needs to spend time working on tutorial problems.

Approach

This paper will present data showing that the time spent on directed practice of tutorial problems is highly correlated with the improvement in the students' marks. Using a proprietary computer package (MyMathLab Global by Pearson Publishers) to obtain practice time and the difference between the marks of a diagnostic mathematics test in the first week of the semester and the marks in the final exam a correlation analysis will be undertaken.

Results

This analysis will show that the more time that a student spends on directed practice the greater will be their improvement in marks.

Conclusions

A problem with this study is that correlation is not causation and other factors may be influencing the correlation. The paper will discuss these points in detail and show that the correlation analysis is likely to have a high validity and that the initial hypothesis is reasonable.

Keywords: Directed-practice, feedback, practice-time.

Introduction

As all engineers are fully aware, the mathematics in engineering courses is used not only for calculating solutions to problems, but for many other functions. Mathematics is a tool for seeing patterns and interconnections, it is a tool for facilitating understanding, a language for teaching and explaining technical concepts, and most importantly it is a language that facilitates self-study and continuing professional development. Modern technology is changing at such a rate that many products and processes are obsolete within a short time. It is therefore essential that engineers have the tools to enable them to keep up to date: mathematics is one of the most important of these tools.

It is therefore necessary that engineers know various mathematical procedures but, more importantly, that they understand them and are fluid in them, i.e. can use them easily and almost without thinking.

Background to the Study

The Importance of Working Memory for Learning

When students are learning a new concept, it is their working memory that is being used to understand the new topic and relate it to other relevant concepts (Baddeley, 2004). Unfortunately, human working memory is limited. It can hold about 7 independent items in storage at a time (Baddeley, 2004). Therefore, when teaching a new topic, lecturers must take care not to fill the students' working memory with items that are not directly related to the concept being taught (Barclay, Bransford, Franks, McCarrel, and Nitsch 1974). If a lecturer is using mathematics as an aid to explain a new engineering concept, the mathematics that the lecturer uses must be mathematics that the students are fluid with. That is, mathematics that the students have stored in their long-term memories because long term memories have the property that they are able to access concepts rapidly, subconsciously and almost without thinking (Willingham, 2009). This is necessary so that the lecturer can explain the new concept without the student having to use up limited working memory to understand the mathematics underlying the new concept before they can direct their working memory to the new concept. If the students are using their limited working memory to understand the underlying mathematics they will not have sufficient reserves of working memory to allocate to fully understanding the new engineering concept which, in turn, will be detrimental to their learning (Cumming and Elkins, 1999).

In order to make the mathematics fluid and to prevent it from using up limited working memory while teaching other engineering concepts it is necessary that the students have transferred the key mathematical concepts to their long-term memory. This is achieved via directed practice of the basic mathematical procedures and concepts together with regular feedback (Willingham, 2009).

Becoming an Expert

The research into the abilities and creation of experts is relevant to the above discussion. Ericson, et.al. have shown that in order to become an expert in a particular area such as violin playing, chess, etc. it is necessary for the average person to spend about 10 000 hours of directed, goal oriented practice with regular feedback (see graph below) (Ericson, Kampe, and Tesch-Romer, 1993). In addition, a person with a background of directed practice in an area has increased ability to concentrate on topics in that area (Brown, Roediger III, McDaniel, 2014). Anecdotally, many of our students seem to have difficulty with engagement and concentration.

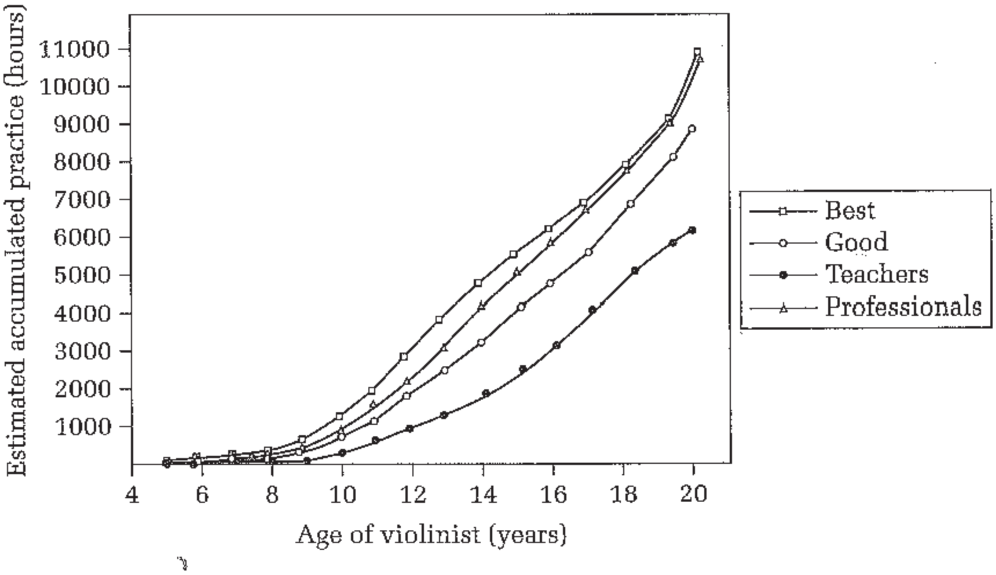

Figure 1: Ericson's data for violinists' practice time (Ericson, et.al., 1993)

An expert in a particular field has the ability to see the solution to a problem in that field rapidly and unconsciously without using significant amounts of working memory (Ericson, Kampe, and Tesch-Romer, 1993). Lecturers are experts in their fields and therefore need to keep the above in mind when dealing with students learning a new topic. That is, what is automatic and immediately obvious to the lecturer is unlikely to be so to the student (Willingham, 2009).

Aims of Directed Practice

As discussed above, the overall aims of directed practice in mathematics is to make the students fluid and automatic with mathematics, and to have the ability to retrieve basic mathematical concepts rapidly and subconsciously, (Alexander, Kulikowich, and Schulze, 1994). In addition, it has been found that students that are fluid with mathematics are more likely to see the deep structure within mathematics than those who do not have mathematical fluidity (Schacter, 2002).

In order for practice to be effective it must have the following characteristics:

- The person practicing must practice beyond perfection (Bahrick and Hall, 1991). That is, the person practicing must not stop practicing when she can do a particular practice item once correctly but repeat it a number of times.
- The practice must be directed, have a goal and receive regular feedback (Kang, McDermott, and Roediger, 2007; Gladwell, 2008).
- The basic concepts underlying the practice item must be regularly reviewed (Ellis, Semb, and Cole, 1998; Bahrick, and Hall, 1991).
- The practice should be distributed in time and not concentrated in one long session (Soderstrom and Bjork, 2014).
- The learners must concentrate on what they are doing and think about what they are doing (Willingham, 2009).
- Practice of different concepts should be interleaved with each other rather than doing one concept then the next, etc. (Brown, et.al, 2014).

Study Conducted at the Manukau Institute of Technology

Structure of the Study

The study that is the subject of this paper was conducted at the Manukau Institute of Technology, it involved 31 students, and it dealt with the first-year mathematics paper: Engineering Mathematics 1 (141.514). This paper is the first of two one-semester mathematics papers studied during the three-year engineering degree at the polytech. A one semester paper runs for 15 weeks and consists of 3 hours of lectures plus one tutorial hour per week. In addition, the students are expected to do 6 hours of self-study per week per subject.

During week one the students were given a diagnostic test based on the year-eleven school mathematics syllabus. The reason for choosing the year-eleven material was the students have to have year-thirteen mathematics to get entry to the three-year engineering degree and, therefore, should be able to do year-eleven school mathematics without any difficulty. The mark obtained by the students on the diagnostic test was then compared with their mark in the final end-of-semester exam as described below. It is interesting to note that 16 out of 31 students failed (< 50%) this diagnostic test and the average mark was only 45.6%. This confirms anecdotal evidence claiming the schools are not adequately preparing students for tertiary study.

In order for the students to get directed practice in the basic mathematic concepts an online package published by Pearson's (MyMathLab Global) was used. A test bank of 11 quizzes with each quiz consisting of about 30 questions was set up. Each quiz covered a major topic in the Mathematics 1 syllabus, e.g. matrices. The quizzes were allocated 15% of the students' final mark to encourage the students to do the quizzes, i.e. seven quizzes were allocated 1% each and 4 quizzes, on more important topics, were allocated 2% each. In addition to the quizzes the students sat three class tests worth 35% in total and an end-of-semester exam worth 50%.

The quizzes were done in a collaborative environment in order to get regular feedback. That is, the students could discuss the problems with each other, they had access to a tutor for one hour per week, and the online package had help functions. In addition, the students could do the quizzes off campus and could get help from family, friends, etc.

The online help functions for the quizzes consisted of access to an e-book that automatically provided the students with a textual explanation of the theory behind the problem that they were currently working on. In addition, the online help had a "hint" function that showed the students a step-by-step procedure for any problem that they were currently working on.

The students could do the quizzes as many times as they wished and the highest mark achieved for any particular quiz was recorded as the student's mark. Each quiz question for a particular topic had the same mathematical structure but different numerical values so each student did a numerically different set of quiz questions for each topic.

As discussed above, the aim of this directed practice was to improve the fluidity of the students with basic mathematics concepts.

Results of the Study

Detailed results comparing the improvement in the student marks with the time spent on the quizzes are given in the appendix below.

As shown in a previous paper (Shepstone, 2016), the effect size of the improvement in student marks from the diagnostic test to the final exam was 0.7 (0.4 is regarded as good in the educational setting, Hattie (2009)) and the Student's t-test showed that the means of the diagnostic test marks and the final exam marks were significantly different. These results showed that the students had significantly improved their mathematical performance between the diagnostic test and the end-of-semester exam.

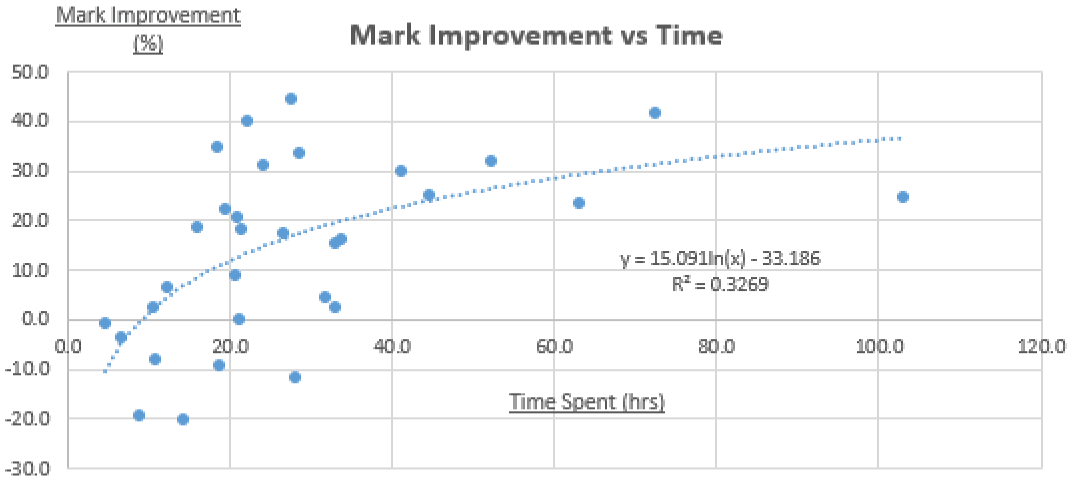

Figure 2: Mark improvement vs time regression analysis

The current study compared the improvement in the student's results between the diagnostic test and the end-of-semester exam with the amount of time spent by the students on the quizzes as shown in the graph above.

To do the analysis shown in the graph it was assumed that the students' improvement in mathematics marks relative to the time spent on the quizzes would follow a traditional learning curve. That is, the learning would be more rapid initially and then increase at a diminishing rate as more time was spent on the quizzes. Therefore, a log curve was fitted to the data as shown on the graph; the equation of this curve is also shown on the graph. The R^2 of this curve is 0.33 showing that this curve explains 33% of the variation in the data. In other words, it may be hypothesised that the time spent on the eleven quizzes explained 33% of the improvement in the students' marks. Alternatively, Figure 2 shows that for an average student to improve her marks by, for example, 22% she needs to spend 40 hours working on the quizzes.

Discussion of the Results and Limitations of the Study

Considering that the quizzes made up only 15% of the students' final mark this result shows that the quizzes had a proportionally large effect on the students' results.

The remaining 66% of the variation in the data was probably due to a number of factors. As the graph shows, a number of students made improvements in their marks that were significantly better than the regression curve. This could be because those students spent time exploring why they got a question wrong or they engaged with the lectures more effectively and thus made more rapid progress. Also, some students have not studied mathematics for a number of years and the quizzes may have provided a reminder and revision of material they already knew. That is, this material may have already been stored in their long-term memory and the quizzes brought it to the surface again.

Other students made improvements in their marks that were significantly worse than the regression curve and, in a few cases, were even negative. This negative variation in the data could be because some students found the volume of work involved in the Engineering Mathematics 1 course was too much and they became more confused as the course progressed. In addition, these students may not have engaged with the lectures and may not have tried to understand why they had got problems wrong on the quizzes but merely continued to the next problem. The time spent on a quiz is a proxy measure for how well the students actually engaged with the quiz. It therefore, does not indicate how well this time was utilised for effective learning. As the graph below shows (the horizontal axis is the student number) some students' marks improved in direct relation to the time that they spent on the quizzes whereas other students' marks showed a negative correlation indicating that these students did not engage effectively with the quizzes.

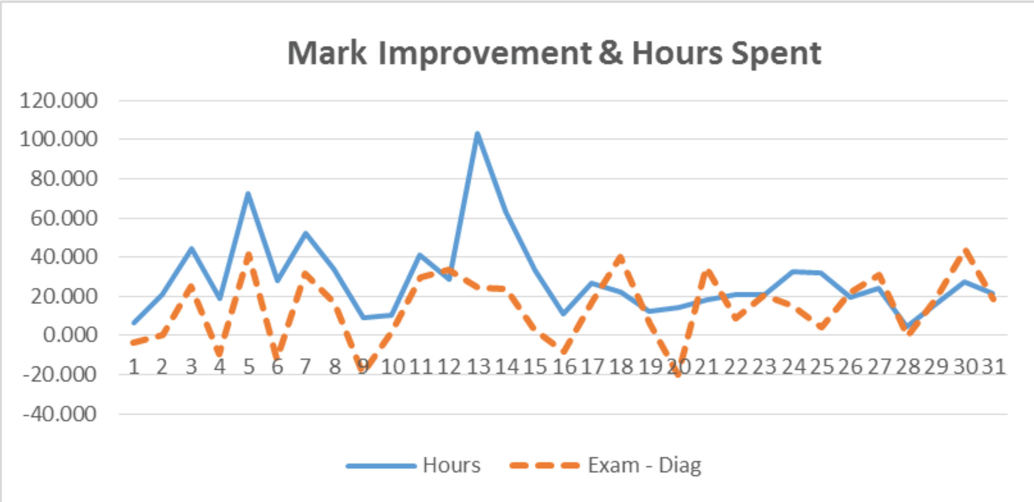

Figure 3: Mark improvement and time spent on quizzes.

In addition, the data in the appendix shows that the average student spent 1 hour 7 minutes per week working on the quizzes in excess of the one hour timetabled tutorial time. Considering that students are expected to spend 6 hours per week outside of timetabled time working on each subject this 1 hour and 7 minutes is not impressive. (Admittedly, the students also had to study for the three tests and the final examination but it is unlikely that they spent 4 hours and 53 minutes on these activities per week.)

This study has a number of limitations. Firstly, correlation is not causation, however it is reasonable to hypothesise that time spent doing quizzes has a casual effect on the students' results. Secondly, this study is small as it involves only 31 students so it shall be run for a number of semesters to see whether these results are robust. In addition, it would be advantageous for an independent polytech to repeat the study to see if they obtain similar results. Thirdly, this study was not a blinded study because of ethical considerations. The ethics committee required that all the students be taught in the most effective way possible which meant that all the students had to do the quizzes and it was not acceptable to divide the study into two halves with only half the group doing the quizzes. Fourthly, the end-of-semester examination was significantly more difficult than the diagnostic test because it included topics such as calculus, matrices, and complex numbers which the diagnostic test did not. Therefore, these results are probably an underestimate of the improvement that the students made. Finally, this study ran for only 15 weeks which is a short time for any substantial improvement in a student's mathematical ability to be made, particularly in the light of Ericson's work which indicates that substantial amounts of time on directed practice is needed to make major improvements in one's abilities.

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Appendix

Table 1: Raw data used for analysis

	BET Maths Results (2016-1, 2016-2, 2017-1)						
		Time Spent					
Student No.	H:Min:Sec	Days	Hours	Exam mark	Diagnostic Mk	Estimated	Exam - Diag
7910	6:32:47	0.27277	6.546	38.8	42.3	50.0	-3.5
2274	21:08:16	0.88074	21.138	34.7	34.6	75.0	0.1
9222	44:41:30	1.86215	44.692	72.2	47.4	60.0	24.8
3598	18:39:53	0.77770	18.665	70.0	79.5	90.0	-9.5
2079	72:28:47	3.01999	72.480	64.7	23.1	40.0	41.6
9447	28:02:41	1.16853	28.045	53.5	65.4	30.0	-11.9
9613	52:18:31	2.17953	52.309	44.6	12.8	10.0	31.8
6627	33:52:04	1.41116	33.868	20.2	3.9	10.0	16.3
7066	8:49:21	0.36760	8.823	42.3	61.5	60.0	-19.2
9450	10:42:14	0.44600	10.704	17.9	15.4	10.0	2.5
0545	41:04:28	1.71144	41.074	46.7	16.7	50.0	30.0
6575	28:33:47	1.19013	28.563	96.3	62.8	75.0	33.5
5358	103:12:53	4.30061	103.215	47.6	23.1	50.0	24.5
3406	63:02:56	2.62704	63.049	85.0	61.5	50.0	23.5
4856	33:06:53	1.37978	33.115	66.7	64.1	87.0	2.6
0466	10:51:01	0.45209	10.850	65.0	73.0	70.0	-8.0
2063	26:39:50	1.11100	26.664	73.4	56.0	70.0	17.4
9450	22:09:39	0.92337	22.161	75.0	35.0	10.0	40.0
0313	12:18:36	0.51292	12.310	46.4	40.0	80.0	6.4
1742	14:24:26	0.60030	14.407	55.8	76.0	60.0	-20.2
2016	18:28:37	0.76987	18.477	69.7	35.0	75.0	34.7
6210	20:39:43	0.86091	20.662	62.9	54.0	50.0	8.9
9467	20:50:16	0.86824	20.838	66.7	46.0	40.0	20.7
6326	32:55:29	1.37186	32.925	73.4	58.0	60.0	15.4
0063	31:46:34	1.32400	31.776	87.5	83.0	85.0	4.5
1535	19:22:57	0.80760	19.383	82.1	60.0	60.0	22.1
2991	24:13:32	1.00940	24.226	45.0	14.0	30.0	31.0
8554	4:35:33	0.19135	4.593	3.3	4.0	25.0	-0.7
5517	16:01:36	0.66778	16.027	87.5	69.0	85.0	18.5
0088	27:29:42	1.14563	27.495	71.3	27.0	50.0	44.3
1865	21:21:45	0.89010	21.363	86.3	68.0	60.0	18.3
		Average	28.724	59.8	45.6	53.5	14.2
		Home av/week	1.115				
		Std dev	20.8	22.2	23.4	24.0	17.9
	T-test shows means are significantly different between the exam mark and the diagnostic mark.						

Understanding Engineering Competencies in Practice and the Educational Implications

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SESSION C1: Integration of theory and practice in the learning and teaching process, S1: Is Integrated Engineering Education Necessary?

CONTEXT Engineering professionals and educators have different interpretations or perspectives on certain engineering competency items, for example, mathematical modelling. The question here is how such differences impact the structuring and interpretation of engineering competencies at the general level.

PURPOSE This paper responds to the following questions: How can certain engineering competency items be clustered with others? Is there empirical evidence to support such structures?

APPROACH The research questions stems from a comparative literature review of existing national and international engineering competency standards. Empirical data used in this paper was collected from a small-scale survey. Social Network Analysis (SNA) was used as the method for data analysis – engineering competency mapping.

RESULTS A set of conceptual maps have been made to depict the clustering of 60 engineering competency items identified in a real-life engineering company in China.

CONCLUSIONS It is argued that the Social Network Analysis algorithm can be appropriated for the study of engineering competencies. This algorithm provides indicators of identifying relatively "important" competency items, which create implications for undergraduate engineering practice programs.

KEYWORDS Engineering Competencies, Conceptual Map, Social Network Analysis

Introduction

Despite scientific and technical challenges that engineers have confronted through history, a long lasting non-technical challenge may seem to be more evident in recent years. Such a challenge may be termed as “an identity challenge” (Christensen et al., 2009). This term can be interpreted from educational as well as industrial and/or professional perspectives.

Engineers Australia provides a typical professional interpretation of this term in its Stage 2 Engineering Competency Standards mentioning that “the community has certain expectations of experienced professional engineers, their competence, how they apply this competence and how they will conduct themselves” (Engineers Australia 2012, p.2). This indicates that engineering competency may be critical in shaping engineers’ professional identity.

Studies of engineering competencies can be approached from a comparative literature review of existing engineering competency standards and/or models. Not only do the narratives of certain competency items lead to interpretations from different perspectives, but also the structures of mapping engineering competency items may indicate different approaches of competency building.

From a brief comparative study of some existing engineering competency standards/models developed in different countries – Australia, United States, and China – mathematical modelling is found as a competency item which exemplifies a tension of interpretation from two different perspectives – the practical vs. the theoretical. On one hand, modelling is perceived as a practical skill of simulating real world problems, depicting the ability of problem solving (Dowling & Hadgraft, 2013 and International Engineering Alliance, 2013). On the other hand, it can also be perceived as a major part of theoretical knowledge focusing on understanding engineering sciences (United States Department of Labour, 2015). In between, modelling may not be considered as an independent competency item (Ministry of Education, 2013 and Engineers Australia, 2012).

This complexity poses two questions. First, how can competency items be clustered to create a structure for better understanding? Second, is there empirical evidence to support such a complexity in the real-life workplace?

This paper presents a method of mapping engineering competency items with empirical data collected from a Chinese nuclear power engineering company.

Research

The research question of this paper comes from a comparative literature review. Empirical data used in this paper was collected from a small-scale survey. Social Network Analysis (SNA) is used as the method for data analysis – engineering competency mapping.

Literature Review

The scope of literature covers 5 engineering competency standards or graduate and professional attributes standards published by national and international agencies from 2012 to 2015. These documents are listed as the following:

- Stage 1 Engineering Competency Standards, Engineers Australia 2012 (EA1)
- Stage 2 Engineering Competency Standards, Engineers Australia 2012 (EA2)
- Environmental Engineering Graduate Capabilities and the Stage 1 Competency Standard in the Define Your Discipline (DYD) project, Office for Learning and Teaching, Department of Industry, Innovation, Science, Research and Tertiary Education, Sydney 2013 (DYD)

- Graduate Attributes and Professional Competencies Version 3, Washington/Sydney/Dublin Accords, International Engineering Alliance 2013 (IEA)
- Nurturing Outstanding Engineers – General Standards, Ministry of Education China 2013 (MOE)
- Engineering Competency Model, United States Department of Labour 2015 (AAES)

A summary of the literature review can be seen in Table 1:

Table 1: Comparative review of competency standards

	MOE	IEA	EA1	EA2	AAES	DYD
Level	BA/MA/PhD	Graduate/Professional	Graduate	Professional	Professional	Graduate
Style	Summarized narratives	Tables	2 Column table	3 Column table	Pyramid in tiers	4 Dimensional diagram
Engineering Discipline	All	All	All	All	All	Environmental
Number of competency items	Not specified	Graduate:12 Professional: 13	16 Elements + a list of indicators of attainment	16 Elements + a list of indicators of attainment	Tier1:7 Tier2:7 Tier3:10 Tier4:10 Tier5:Not specified	Technical:7 Process:6 Generic:7 Context: Not specified

Table 1 demonstrates several methods of identifying, structuring and presenting engineering competency items at graduate and professional levels. Such diversity stems from what H.J Passow and C.H. Passow (2017) have identified as a language problem – consistency of wording and difficulty in defining the scope – in a meta-analytical research of this topic.

Although, these well-established standards revealed the complexity of presenting engineering competency items, they did not provide effective ways – in terms of visual expressiveness – of illustrating the “relative importance” (Passow & Passow, 2017) of some items. On top of that, the practical vs. theoretical tension embodied in such competency items remains ambiguous. This ambiguity can be exemplified by the cluster of some items with similar features.

Another example is “procedure compliance”. In the tier 4 competencies in the AAES competency model, engineering sciences are grouped with procedure compliance competencies such as quality control and assurance (United States Department of Labour, 2015). While Engineers Australia Stage 2 Standards (2012) address the routine aspects in the interpretation of individual responsibility. This indicates two possible focuses for the notion of procedure compliance, in the sense that academics may emphasize the systematic approach of engineering design or systems engineering based flows of work, which is, in fact, an academic training, while professionals focus on compliance of organizational routines manifested by individual responsibility.

The academic aspect of procedural competencies is identified as a series of process capabilities in the DYD project (Dowling & Hadgraft, 2013). Although the Chinese standards touched upon both aspects, they were all regarded as a form of knowledge because graduates are only required to be familiar them. Evidence for application seems quite obscure in the Chinese standards (Ministry of Education, 2013).

Empirical data collection

Empirical data used in this paper was collected from a Chinese nuclear power engineering company, which included almost all major engineering disciplines and typical engineering activities such as design, procurement, construction and commissioning. In this respect, such data represents understanding of engineering competencies from a professional perspective in China. Two methods of data collection were adopted. In the first phase, a free listing survey was carried out and in the second phase, another group of participants were invited to take part in a sorting survey.

The free listing survey involved 14 participants. They were asked to list at least 20 competency items related to their daily work. From a disciplinary perspective, these participants included nuclear physicists, mechanical engineers, structural design engineers, digital control engineers and electrical engineers.

At the beginning of the free listing survey, initial data collected represented a range of narrative styles, from summarized sentences to short phrases and words. All these were in Chinese. This brought in two major difficulties. The first difficulty is that expressions of engineering competency items in a synthetic way will lead to unavoidable misinterpretations by the researcher, attempting to break down such synthesized information. It also generated a difficulty for translating the research findings into English, in order to perform a study in an international context, hence to depict possible cultural characteristics. One example of this can be found in Appendix 1 C47 Philosophical Thinking. This translation came out from a compromise of both its English and Chinese meanings. In fact, in most cases, critical thinking in English may be the most appropriate equivalent. But, the notion of critical thinking in Chinese normally refers to dialectics which changes the original meaning to a limited scope. However, using the term philosophical thinking may bring in some redundancy with C2 Logical Reasoning. As a consequence, participants were asked to provide answers in short phrases in the second round. Eventually, 60 relatively independent items (refer to Appendix 1) were identified and translated into English by the researcher.

This list of 60 engineering competency items was used as an input for the following sorting survey which involved 31 participants who were asked to sort these 60 items into groups based on whatever criteria that the participants considered appropriate. Each individual sorting result can be illustrated by a 60X60 data sheet with “1” indicating that those two competencies have been grouped together while “0” indicates those were not grouped together (Appendix 1).

	A	B	C	D	E	F	G
1		C1	C2	C3	C4	C5	C6
2	C1	1	1	0	0	0	1
3	C2	1	1	0	0	0	1
4	C3	0	0	1	0	0	0
5	C4	0	0	0	1	1	0
6	C5	0	0	0	1	1	0
7	C6	1	1	0	0	0	1
8	C7	0	0	0	1	1	0
9	C8	0	0	1	0	0	0
10	C9	1	1	0	0	0	1
11	C10	1	1	0	0	0	1
12	C11	0	0	1	0	0	0
13	C12	0	0	1	0	0	0

Figure 1: Individual sorting sheet

Thirty one individual sorting sheets were then aggregated with each participant given a weight of 1/31 (the arithmetic mean).

	A	B	C	D	E	F
1		C1	C2	C3	C4	C5
2	C1	1	0. 354839	0. 193548	0. 419355	0. 451613
3	C2	0. 354839	1	0. 548387	0. 193548	0. 225806
4	C3	0. 193548	0. 548387	1	0. 193548	0. 16129
5	C4	0. 419355	0. 193548	0. 193548	1	0. 83871
6	C5	0. 451613	0. 225806	0. 16129	0. 83871	1
7	C6	0. 322581	0. 612903	0. 290323	0. 322581	0. 322581
8	C7	0. 580645	0. 258065	0. 16129	0. 580645	0. 483871
9	C8	0. 129032	0. 290323	0. 354839	0. 129032	0. 129032
10	C9	0. 548387	0. 483871	0. 290323	0. 483871	0. 483871
11	C10	0. 096774	0. 354839	0. 290323	0. 096774	0. 129032
12	C11	0	0. 064516	0. 290323	0. 032258	0
13	C12	0	0. 064516	0. 290323	0. 032258	0

Figure 2: Aggregation (n=31)

This aggregated data sheet is used as the input data for a Social Network Analysis (SNA) to generate a graphic structure of engineering competency items identified in this company. SNA has been used to study individual knowledge sharing relationships in a company and the validity of depicting relationships of concepts (Brandes & Erlebach, 2005). Hence it was assumed to be an effective way of giving a visual structure for engineering competency items. A high number indicates an average high level of relatedness.

Mapping Engineering Competencies by SNA

In order to render an SNA diagram using UCINET 6.0, a threshold value indicating valid relationship is critical. Theoretically, the strength of relationship between each pair of competency items can be quantified by the aggregated value in Figure 2. In practice, such threshold value is found on a trial-error test. Three threshold values were tested. The first possible value is 8/31=0.258 which indicates that approximately1/4 of the participants consider that such a pair of items relate to each other. In this respect, 0.258 can be considered as a possible threshold value. The second possible value tested is 16/31=0.516 (1/2) and the third value is 24/31=0.774 (3/4).

At each threshold value the SNA diagrams can be illustrated as the following:

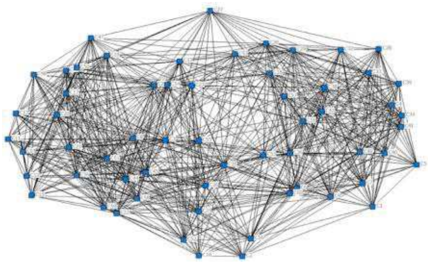

Figure 3: SNA mapping at the value of 0.258

In Figure 3 (threshold = 0.258), nodes are almost evenly distributed. Inter-relationships among nodes are too complicated. 1686 ties were identified above the threshold.

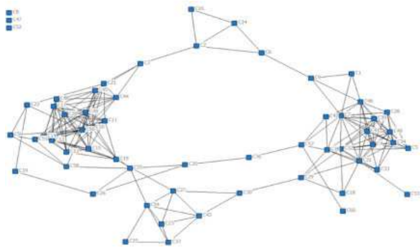

Figure 4: SNA mapping at the value of 0.516

In Figure 4 (threshold = 0.516), nodes can be regarded as clustered into 4 groups with some bridging nodes connecting the major clusters. Three isolated nodes are listed on the top corner. They are C8 Objectivity, C47 Philosophical thinking and C52 Social concerns. An explanation for their isolation perhaps derives from the ambiguity of their definitions. 404 ties were found.

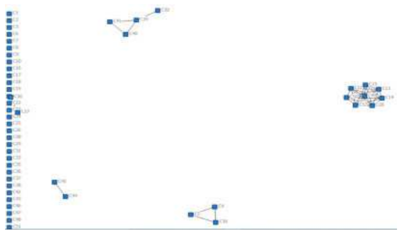

Figure 5: SNA mapping at the value of 0.774

Figure 5 is the SNA diagram rendered at the threshold value of 0.774. A long list of isolated nodes appears at the left margin. Five groups of competencies are identified. 74 ties are visible mainly within the largest group (all of them are generic items). The relationships between the largest group and other nodes are not presented. Therefore, it is an over-simplified demonstration of engineering competencies in the workplace.

Node attributes such as *degree centrality* (the number of links incident upon a node) and *betweenness* (the degree of which nodes stand between each other indicating control of the network) are useful to depict relative “importance” of certain nodes in an SNA diagram (Brandes & Erlebach, 2005). Modifying Figure 4 with these measurements leads to further interpretations of some “important” nodes (See Figures 6-7). Further analysis on the data is based on Figure 4, using a threshold value of 0.516.

Figure 6 shows the SNA diagram at 0.516 modified by setting node size based on *degree centrality*, which is a count of connected nodes.

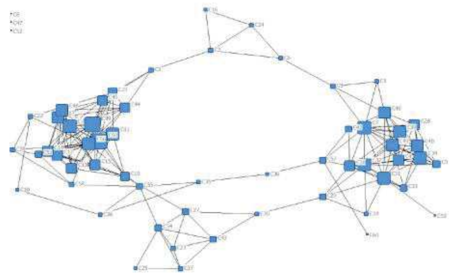

Figure 6: SNA mapping at 0.516 Degree Centrality

Figure 7 shows the SNA diagram at 0.516 by setting node size based on *betweenness*.

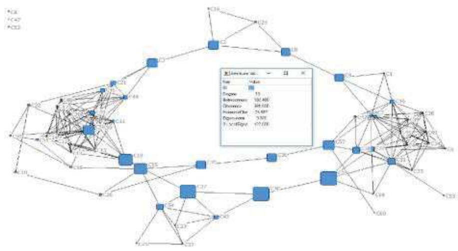

Figure 7: SNA mapping at 0.516 Between-ness

Figure 8 derives from Figures 6 and 7 by picking up significant nodes indicated by *degree centrality* and *betweenness* measurements. Node geometric locations are kept unchanged.

				Context							
				C16 Common Sense	2, 0	C24 Problem Simplification	3, 12				
Generic				C2 Logical Reasoning	4, 206	C6 Problem Clarification	3, 176				
		C3 Curiosity	4, 200					**C9 Mathematical Modelling**	**4, 179**	***Technical***	
C56 Resolve Confrontation	**13, 226**									**C7 Drawing**	**13, 192**
C50 Emotional Control	15, 73									C31 Project Experience	12, 145
C49 Work under Pressure	15, 73									C41 Operation and Maintenance	11, 6
C48 Sceptical	11, 6									C40 Erection and Commissioning	11, 6
C12 Prudence	10, 8									C32 Technical Standards	12, 95
C14 Hardworking	10, 8									C38 Reference Projects	10, 141
C20 Work in a Group	13, 24									C34 Manufacturing Techniques	12, 7
C17 Open Minded	11, 6			***Process***						C57 Literature Study	5, 215
		C19 Aesthetics	8, 278	**C55 Variations**	**5, 263**			C30 Industrial Health and Safety	3, 343		
								C29 Procedure Compliance	**5, 340**		
				C27 Environmental Consciousness	5, 321	C43 QA and QC	5, 68				
				C54 Risk Control	6, 122	C23 Cost Control	4, 3				
				Node	Name	Degree Centrality	Betweenness				
				C7	Drawings	13	192				

Figure 8: SNA mapping interpretation

Engineering competencies in Figure 8 are divided into 4 groups, a *generic* group, a *process* group, a *context* group and a *technical* group. A detailed illustration of constituents in each group can be found in Appendix 2. This finding largely corresponds to the DYD research.

In this figure, “important” engineering competencies can be defined as those with both high values of *degree centrality* and *betweenness*. High values of these measurements represent both high frequency of appearance of one competency item in multiple types of engineering tasks and the impact of it to overall performances in work.

Regarding an engineering project as a social process, resolving and assimilating different opinions serves as the theme of the *generic* group (Bucciarelli 1996). This may be the reason why C56 ‘Resolve confrontations’ is identified as the most important *generic* item, with both high value of *degree centrality* and *betweenness*. The node connects to 13 engineering competencies and is situated in a “favoured” position to facilitate overall practical performances.

In the *technical* group, C7 Drawing, is considered as the most important item because the focus of the nuclear power engineering company is design. In reality, making drawings is a fundamental technical skill that a design engineer needs to master in order to pass complex technical information to others, including to construction teams.

Compared to the *generic* and the *technical* groups, there are fewer nodes in the *context* and *process* groups. But, on average, they hold higher *betweenness* values. This suggests that they serve as the major brokering items between personal attributes and individual technical knowledge and skills.

C9 Mathematical Modelling is placed in the *context* group adjacent to the technical group because in real life engineering practice, modelling requires a deep understanding of the context of application. In this respect, it explains why a high *betweenness* value appears.

C55 (Contract) Variations is placed in the *process* group but serves as linkage between *generic* and *process* competencies because, in practice, variation orders often re-shape technical and commercial agreements. The negotiation process of agreeing to a variation involves personal attributes.

C29 Procedure Compliance is a brokering competency that connects the *process* group and the *technical* group. The earlier discussion in the literature review is supported by the particular geometric location of this node.

Discussions and Implications

The research presented in this paper demonstrates the usefulness of conceptual maps (Wheeldon & Ahlberg, 2012) in the study of engineering competencies. The Social Network Analysis (SNA) algorithm has been used as a mapping tool to model perceived relatedness between competencies. It sheds light on a previous attempt to use the Multidimensional Scaling (MDS) algorithm (Hadgraft, Tilstra & Thebuwana, 2014) to generate statistically more rigorous concept maps – in terms of competency item clustering. Compared to MDS maps, SNA maps may have stronger expressiveness in relationship interpretations and pointing out relative “importance”.

Undergraduate engineering education in China is experiencing a practical shift and has long gone into internationalization. This perception can be strengthened by the nation’s participation in the Washington Accord in the year 2016 (International Engineering Alliance, 2017). However, what can be observed in Table 1 is that many differences between China’s domestic engineering graduate competency standard and the international standard exist. These differences may lead to some difficulties for academics in other countries to understand the Chinese paradigm of engineering education. This paper provides some empirical evidence and translations to fill this gap.

Rather than a historical perspective towards the characteristic of Chinese engineering culture, this paper proposes an analytical approach. As is indicated in this paper, the structural and narrative features of engineering competency items gathered from Chinese engineering professionals may lead to new understandings of the contemporary reality.

From an educational perspective, *process* and *context* competencies should be emphasised in the practice programs such as projects and internships in undergraduate engineering education. *Process* competencies should not be limited to the knowing of particular manufacturing or construction processes based on theoretical demonstrations. In fact, process competencies largely refer to compliance to certain organizational regulations and managerial agendas. The attainment of these competencies requires an understanding of both an organization and the scope of the tasks defined in a particular context.

Context competencies support *technical* performances because problem solving starts with problem identification and definition in which an understanding of the context is a pre-requisite. In this respect, they are likely the competencies that can better be developed in the workplace.

Conclusions

This paper has presented a way of creating a conceptual map by Social Network Analysis for engineering competencies with survey data collected from a real-life company. The authors acknowledge that language translation has likely had some impact on the study.

The paper reveals different perspectives of certain engineering competency elements and how such differences are represented in the workplace. Four clusters of skills: *generic*, *process*, *context*, and *technical*, have been revealed by the modelling, in a similar way to the DYD research mentioned earlier.

The research described in this paper supports the notion that conceptual maps "assist people to produce patterns of how they organized and structured their thoughts; concept maps were later developed into meta-cognitive tools for learning and teaching" (Wheeldon and Ahlberg, 2012, p23). Specifically, the Social Network Analysis algorithm can be appropriated for the study of engineering competencies.

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Appendix 1 Engineering competency items sorting example from the company

No.	Competency	Sorting	No.	Competency	Sorting
C1	Experiments and tests	1	C31	Project experience	1
C2	Logical reasoning	1	C32	Technical standards	3
C3	Curiosity	2	C33	Industrial trends	3
C4	Knowledge of one discipline	3	C34	Manufacturing techniques	3
C5	Cross-disciplinary knowledge	3	C35	Project goals	1
C6	Problem clarification	1	C36	Feasibility study	1
C7	Drawing	3	C37	Marketing	2
C8	Objectivity	2	C38	Reference projects	3
C9	Mathematical Modelling	1	C39	Materials	3
C10	Interfaces	1	C40	Erection and commissioning	3
C11	Honesty	2	C41	Operation and maintenance	3
C12	Prudence	2	C42	Foreign language	3
C13	Patience	2	C43	QA and QC	2
C14	Hard-working	2	C44	Judgment	2
C15	Persistence	2	C45	Independent thinking	2
C16	Common sense	1	C46	Coding and Software	1
C17	Open-minded	2	C47	Philosophical thinking	2
C18	Compliance with regulations	1	C48	Sceptic	2
C19	Aesthetics	2	C49	Work under pressure	2
C20	Work in a group	2	C50	Self-control	2
C21	Creativity	2	C51	Leadership	1
C22	Communication	1	C52	Social concerns	1
C23	Cost control	2	C53	Peer review	1
C24	Problem simplification	1	C54	Risk control	2
C25	Scope of work	2	C55	Variations	1
C26	Planning	3	C56	Resolve confrontations	2
C27	Environmental consciousness	2	C57	Literature study	3
C28	Ergonomics	3	C58	Negotiation	1
C29	Procedures	1	C59	Initiative	1
C30	Industrial health and safety	2	C60	Data collection	1

Appendix 2 Engineering competency sorting in 4 dimensions

Generic	Context	Process	Technical	Isolated
C3 Curiosity	C2 Logical reasoning	C23 Cost control	C1 Experiments and tests	C8 Objectivity
C10 Interfaces	C6 Problem clarification	C25 Scope of work	C4 Knowledge of one discipline	C47 Philosophical thinking
C11 Honesty	C9 Mathematical Modelling	C27 Environmental consciousness	C5 Cross-disciplinary knowledge	C52 Social concerns
C12 Prudence	C16 Common sense	C29 Procedures	C7 Drawing	
C13 Patience	C24 Problem simplification	C30 Industrial health and safety	C18 Compliance with regulations	
C14 Hard-working		C35 Project goals	C28 Ergonomics	
C15 Persistence		C36 Feasibility study	C31 Project experience	
C17 Open-minded		C37 Marketing	C32 Technical standards	
C19 Aesthetics		C43 QA and QC	C33 Industrial trends	
C20 Work in a group		C54 Risk control	C34 Manufacturing techniques	
C21 Creativity		C55 Variations	C38 Reference projects	
C22 Communication			C39 Materials	
C26 Planning			C40 Erection and commissioning	
C44 Judgment			C41 Operation and maintenance	
C45 Independent thinking			C42 Foreign language	
C48 Sceptic			C46 Coding and Software	
C49 Work under pressure			C53 Peer review	
C50 Self-control			C57 Literature study	
C51 Leadership			C60 Data collection	
C56 Resolve confrontations				
C58 Negotiation				
C59 Initiative				

TRIZ Education in Mainland China

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SESSION S2: Educating the Edisons of the 21st Century

CONTEXT This paper gives a brief review of the general situation of the TRIZ education in mainland China. A lot of successful cases of TRIZ application all over the world support its effectiveness in research & development, design and manufacturing, etc. In 1987, TRIZ was introduced into China, especially starting from 2007, a variety of TRIZ activities spread rapidly. Yet, the challenges are still remaining. This paper summarizes the current status, addresses the impact of the TRIZ education in China and highlights the challenges ahead.

PURPOSE Share the general situation of the TRIZ education in mainland China to the international community.

APPROACH Seven sections below will be included in the paper, i.e. (1) Introduction, (2) TRIZ educator / Trainer's profile, (3) TRIZ education at university, (4) TRIZ education at industry, (5) TRIZ education at society, (6) Discussion of effects of TRIZ application, (7) Reflection and suggestion.

RESULTS Under the spreading of variety of TRIZ education, hundreds thousands of TRIZ fans are active on the wide stage in different fields. And this will bring the very positive influence to Chinese capacity on innovation.

CONCLUSIONS Several points need to be studied deeply, i.e. how to promote TRIZ Trainer's ability? How can the learner get the concrete effects when they face the engineering problem? Which parts of TRIZ should be taught for different audience?

KEYWORDS TRIZ education, MATRIZ, U-TRIZ, Mainland China

TRIZ Education in Mainland China

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1. Introduction

The publication of the first TRIZ book in Chinese language at Guangdong People's Press - *Creativity as an Exact Science*, translated from Russian by Xiang Wei and Mingze Xu in 1987, is the milestone of TRIZ entrance into mainland China. The same book had been translated again by Guangwei Wu & Shulan Liu and published in 1990 at BEIHANG University Press. Unfortunately, the book, one of 'Man and Creation series', had not drawn much attention at that time. Based on the three most powerful Chinese academic journal electronic platforms, e.g. China Academic Journal Electronic Publishing House, Wanfang Data and VIP Information, only one TRIZ paper (Niu, 1999) was published on the Chinese journals before 2000. In 2001, the TRIZ theory training was introduced in China (Lu, 2017) and TRIZ theory was only used in few fields such as aerospace engineering, military engineering, equipment manufacturing industry etc.

From 2007 on, the innovation method (including TRIZ theory) was promoted vigorously by MST (Ministry of Science and Technology). The specific promoting operation was under the control of The Administrative Centre for China's 21, and then, *China Innovation Method Society* was established. Heilongjiang Province, Sichuan Province and Jiangsu Province were selected as the first batch pilot provinces to do the regional popularization and application of innovation method financed by some national foundations. In 2009, 9 more provinces were added to the pilot provinces pool, afterward, 30 Regional innovation methods to promote the application and service bases had been created by 2016. One of main target of the popularization and application of innovation method is the TRIZ education based on the classical TRIZ.

Since 2012, MATRIZ (International TRIZ Association) series certificate training has been given by Sergei Ikovenko who is the President of MATRIZ. The whole MATRIZ certification training materials with logo of GEN3 Partners (Ikovenko, 2013) began to circulate among the Chinese certificate candidates and the modern TRIZ framework was introduced in the mean time.

In order to cultivate the creative talents in Chinese universities, the Innovative Methodology Teaching Steering Subcommittee was established by Ministry of Education in May, 2013.TRIZ is one of the innovative methodologies. U-TRIZ (Zhao, 2015) was put forward by Min Zhao, Wucheng Zhang, etc. In 2015, and it is gradually becoming the backbone inventive methodology of TRIZ Research Council of China Association of Inventions.

In this paper, the current status of TRIZ education in China will be reviewed, including the educators/trainers, TRIZ education in university, TRIZ education/implementation within industry. Finally, impact of the TRIZ education in China and its perspectives are discussed.

2. TRIZ educators or trainers' profile

In mainland China, all the TRIZ educators or trainers come from 3 main channels, e.g. social channel, semi-official channel, and official channel, which will be introduced in the followings.

2.1 Social Channel

Before 2012

For those TRIZ teachers supported by governmental finance who had no opportunity to participate the formal TRIZ training workshops, self-study almost was the only way to learn TRIZ knowledge in mainland China. During that period of time, classical TRIZ knowledge hierarchy dominated the Chinese TRIZ books. The contents include Ideal Final Result, 8 Laws of Evolution, Technical Contradiction & 40 Inventive Principles, and Physical Contradiction & Methods of Separation, Su-Field Model & 76 Standard Solutions, Scientific Effects Database, ARIZ-85C and Innovative Thinking Methods. Here 'Innovative Thinking Methods' include Nine Screens, Method of Smart Little People, Size-Time-Cost Operator and Golden Fish Method. These TRIZ teachers are real TRIZ fans and exist in the colleges and research institutes.

After 2012

Facing public learners, TRIZ Master Sergei Ikovenko opened the first batch 5-day MATRIZ Level 2 certification training in September 2012 and 13-day Level 3 certification training in August 2013. Both workshops were held in Shanghai, the biggest city in China. The modern TRIZ knowledge hierarchy (Figure 1) was firstly and formally introduced into mainland China.

By September 2017, the number of MATRIZ certified TRIZ specialists has reached 1693, include 903 in level 1, 680 in level 2, 108 in level 3 and 2 in level 4. Many of them are TRIZ educators who spread the modern TRIZ knowledge.

2.2 Semi-Official Channel

TRIZ Research Council of China Association of Inventions is a registered non-government organization. It attracts a lot of TRIZ fans to join in and its research scope is mainly focused on TRIZ. Min Zhao, founder of U-TRIZ, is the director of the council. The first batch **U-TRIZ trainer** classroom training, 24-hour course, was given by Min Zhao in Hangzhou, China in July 2017. 31 people took part in the training workshop. Because of the relative short lifetime of U-TRIZ, the U-TRIZ popularization and application is still in progress.

“**Function-oriented, Attribute-As-Core**” is the theoretical core points of U-TRIZ. Innovation means utilizing the current attributes sufficiently, finding or activating the potential attributes of substance and deploying the attributes to the suitable substance. As a result, new function will appear naturally. Paying attention to the attributes of substance or system is the key point of U-TRIZ.

In the future, U-TRIZ trainers will most likely emerge from the semi-official channel, TRIZ Research Council of China Association of Inventions.

2.3 Official Channel

Most of the earliest TRIZ teachers participated in the innovation method training class given by two training teams: IWINT(a training and consulting company focus on TRIZ) and HUT (Hebei University of Technology), supported by MST. During the training period, a lot of university professors and international TRIZ experts were invited to deliver TRIZ courses. All the TRIZ teacher candidates came from the innovation method piloting provinces. After the training, TRIZ teachers began to do the regional popularization and application of TRIZ in their province.

The knowledge framework taught in the class includes innovative thinking techniques, TRIZ and industry engineering. Therefore, many contents were packaged in the innovative method pool. For example, many other innovative thinking techniques are included and explained in a brief manner, such as Synectics method, QFD, Checklist, SIT etc. TRIZ weighs about 60% of the total scores in the final examination. With the popularization of innovative method, TRIZ becomes the symbol of innovation method and the other two blocks decline gradually. Because classical TRIZ was taught in the classroom, some TRIZ trainers chose to take part in the MATRIZ certificate training courses given by Sergei afterward.

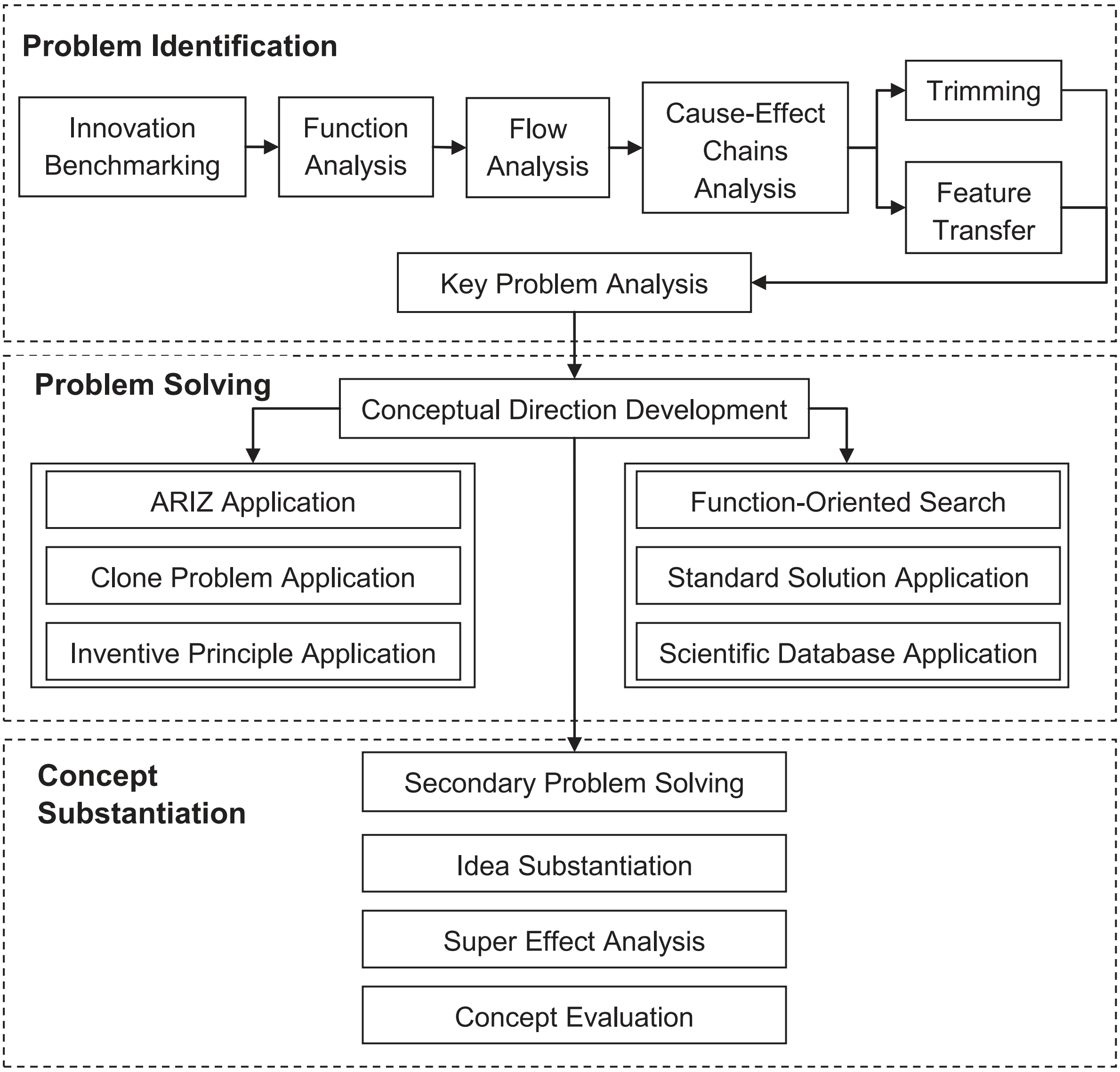

Figure 1: Modern TRIZ (source: Gen3 Partners Product Innovation Roadmap)

3. TRIZ education at University

3.1 Undergraduate students or below

In mainland China, many colleges have set the TRIZ-related courses. There are 4 kinds of the TRIZ education, i.e. elective TRIZ course focus on TRIZ only, the ‘Mechanical innovative Design’ course in which TRIZ only as one chapter be included, ‘Innovation and entrepreneurship’ course in which TRIZ only as one chapter be included, a 1~3-hour lecture popularizing TRIZ knowledge. To be more specific, there is only one university, Northeast Forestry University, to establish the specific teaching and research office focus on TRIZ teaching and research (Fu, 2013).

Recently, innovation and entrepreneurship project is strongly promoted by Chinese Premier Keqiang Li. More and more colleges begin to open and emphasize innovation-related courses. The elective TRIZ course textbook and contents, either classical or modern TRIZ, is highly dependent on teacher and vary from college to college.

Taking “Theory and Application of Modern TRIZ - A Technical Method of Scientific and Technical Innovation” (Table 1) as an example: this course is a public elective course faced on all discipline students in Zhengzhou university, and its intention is to let students know the basic knowledge and logic of TRIZ.

Table 1: TRIZ contents and time distribution

Chapter	time	Chapter	time
● Introduction	2h	● 40 Inventive Principles	8h
● Innovative Thinking Method	2h	● Technical Contradiction	4h
● Function Analysis & Trimming	4h	● Physical Contradiction	2h
● Cause Effect Chain Analysis	2h	● Su-Field Model & standard solutions	2h
● Function-Oriented Search	2h	● Evolution of Engineering System	2h

As a supplement to traditional course, online open course ‘Innovative Method (TRIZ) Theory and Method’ (Gao, 2014) given by professor Guohua Gao from Beijing University of Technology was published online in 2014. TRIZ learning platform ‘ETRIZ’ (Ma, 2017) created by HUT has been published now.

3.2 Master and PhD degree program

Using ‘TRIZ’ as keyword to search the Master and PhD Thesis/dissertations on China Academic Journal Electronic Publishing House, 627dissertations can be retrieved. The top 5 universities are: 1) Hebei University of Technology; 2) Northeast Forestry University; 3) Tianjin University; 4) Shandong University; 5) Zhejiang University.

National Engineering Research Center for Technological Innovation Method and Tool, Hebei University of Technology, Led by Professor Runhua Tan, is the most famous TRIZ research organization in mainland China. There are 19 core TRIZ researchers there. In 2016, The Altshuller Institute for TRIZ Studies awarded Prof. Tan the recipient of the Altshuller Medal for 2016

3.3 Student TRIZ Club or Group

University students in China are members of numerous TRIZ clubs/groups. TRIZ fans participate in various innovative activities and competitions. Many types of innovative competitions are held in China annually. Among them, National "TRIZ" Cup Innovative Competition for College Students is held by Heilongjiang province and is an only TRIZ-specified competition for college students. In the process of taking part in the competition, students invite TRIZ teacher as their tutor. The TRIZ knowledge and application with depth can be employed to guide the students.

4. TRIZ education at Industry

4.1 Popularizing Training Supported by Government

There are two levels TRIZ trainings at industry: one is the national level training and the other is provincial level training. All the expense of training is covered by the national innovative method project. What the enterprises need to do is selecting engineers and organizing the training classroom.

The national level training is undertaken by two national teaching teams: IWINT and HUT. This training faces the national EDEs (Experimental & Demonstration Enterprise) which are selected by MST after evaluating the enterprise's applications. Taking Henan Province as an example, there are only 4 famous enterprises being selected as the national EDE. Two enterprises were trained by IWINT and the other two by HUT. After three stages training, the engineers can obtain the Innovation Engineer Certificate Level1~3 if they pass the examination and project oral defense.

The provincial level training is undertaken by the regional teaching team. As a member of Henan provincial teaching team, I participated three times in TRIZ training for enterprises and taught the topic "Function Analysis and Trimming".

Taking Henan province as an example, the TRIZ training for enterprise includes 3 stages (Table 2).

Table 2: 3-stageTRIZ training contents

First stage (4-Day)	Second stage (4-Day)	Third stage (4-Day)
Opening Ceremony (3h) Creative Thinks (3h) Introduction of TRIZ (3h) Resource Analysis (3h) Contradiction Analysis (3h) 40 Inventive Principles (3h) Discussion and Coaching (6h)	Function Analysis & Trimming (6h) Su-Field Model & 76 Standard Solutions (6) Trends of System Evolution (3h) Fundamental of Patent (3h) Patent Writing (3) Discussion and Coaching (3h)	Presentation (PPT) of engineering problem (2-Day) Discussion & Coaching (1-Day) Examination (Half-Day) Project oral Defense (Half-Day)

4.2 Commercial Training

At the beginning of TRIZ entrance into China, some gigantic enterprises, such as BAO STEEL, tried to deploy TRIZ and spent considerable budget to invite the external professional training and consultant teams. It is said that the outcomes, especially in the realistic problem solving, cannot satisfy company's directors and there is few report regarding BAO STEEL TRIZ on the public media recently.

From 2013 on, Dr. Yongwei Sun, vice president of MATRIZ and MATRIZ Level 4 specialist, joined NICE (National Institute of Clean and Low-Carbon Energy) and was main responsible person for deploying DFSS &TRIZ as a full-time staff. Like GE (General Motors) where he ever worked, Sergei Ikovenko was invited to give the MATRIZ Level 2 & 3 training for NICE's engineers. Dr. Sun takes part in most TRIZ projects as a tutor within NICE.

5. TRIZ education at Society

5.1 MATRIZ Certificate Training from Level 1~3

From 2012, MATRIZ certificate training became popular gradually. By August, there are 4 MATRIZ accredited CEM representatives for Level 1 and 2 representatives for Level 2 in mainland China. MATRIZ certificate trainings are held aperiodically in different city. Usually, Level 1 training is undertaken by Chinese lecturers and Level 2&3 is given by TRIZ Master. Most MATRIZ level 2 & 3 certificate holders are Sergei's students.

5.2 Social network play the very important role

TRIZ popularization depends on the social network to a extents. Instant messengers, such as QQ and WeChat, are the two most used platforms in China, e.g. MATRIZ QQ group 1 with1009 members and MATRIZ QQ group 2 with1071 members. TRIZ Research Council of China Association of Inventions Association QQ group includes 347 members. More than 2000 people are active in the TRIZ social network. TRIZ news, problem discussion and argument are circulated within the TRIZ circle.

Online free TRIZ training course is delivered aperiodically *via* MATRIZ QQ group. More than 20 lectures have been held. Non-scheduled offline TRIZ salons in several metropolises, such as Beijing, Shanghai, Shenzhen, Xi'an, etc. are opened as well.

6. Discussion of TRIZ education effects

6.1 Enterprise Engineers

Having experienced the TRIZ training in the enterprise, engineers reflect that many TRIZ heuristics, such as Smart-Little-People, Nine-Screen, Inventive Principals, etc., can open up their thinking obviously. However, few tutors can show them the breakthrough inventive solving of their real-life problems on-site successfully. On the other hand, engineers who understand and are capable of applying TRIZ have been trapped deeply in their own puzzles without more energy to realize their potential.

All companies are very pragmatic! How to evaluate the effectiveness of TRIZ application in enterprise and make enterprise leadership believe it is worth for popularization of TRIZ continually, using appropriate mechanism to deploy TRIZ project etc., are big challenges without the governmental financial support.

6.2 College Students

In university, majority TRIZ courses are public elective courses during the undergraduate period. Understanding the basic knowledge and logic is the aim of such courses. The students' intention to select this class is to gain additional academic credits. In the meantime, compared with the compulsory courses, TRIZ course requirement is much lower. It is no doubt that TRIZ can open-up students thinking distinctly. However, only TRIZ enthusiasts are willing to actively employ TRIZ systematic methodology in their project when they take part in various competitions.

6.3 Social TRIZ fans

Upon the huge population of mainland China, there are many active TRIZ fans in the social network. The fact of more than 2000 active QQ members shows the evidence. Because of the expensive cost, a few TRIZ fans can afford the formal MATRIZ certificate training. An even fewer TRIZ fans have the opportunity to be guided by the real TRIZ expert hand-by-hand during the process of solving the realistic problem. The fact that few TRIZ books have the step-by-step description of a realistic problem solving using TRIZ in detail brings great difficulty for the TRIZ Fans

7. Reflections and suggestions

Almost everyone thinks TRIZ a great theory during the early stage, but it is not easy to solve the realistic problem using TRIZ completely. The following suggestions and measures should be taken to improve the popularization and application of TRIZ.

7.1TRIZ, itself, needs to be developed and improved continually

There are so many tools in TRIZ which makes TRIZ very complex. But the relationship and logic between each tool is not very clear. It is usually difficult to connect the TRIZ tools with the specific situation. So, TRIZ should be improved following two directions: simple/easy-understandable TRIZ, and exact TRIZ for specific situation.

7.2 TRIZ Trainers need to promote ability

The fact that less successful popularization and application of TRIZ in enterprises is mainly caused by the TRIZ educators who possess insufficient TRIZ expertise. Just like (Belski, 2015) mentioned that:

> *Most of the academics who have tried introducing TRIZ to students did not apply its tools to real projects themselves. They became aware of TRIZ from publications on TRIZ industrial successes or as a result of participation in TRIZ workshops and conferences. The foundations of TRIZ seemed sound to them. TRIZ tools that looked simple to use appeared ambiguous when applied to problems.*

Before all, the TRIZ educators who possess sufficient TRIZ expertise must be cultivated. In the meantime, TRIZ textbooks for different level TRIZ learners must be provided. Otherwise, a lot of TRIZ learners are easy to lose their confidence for TRIZ.

7.3 The realistic effects need to emphasize

In mainland China, people always pay more attention to the complete knowledge which should be taught and neglect the practical effects. It is well known that activity without positive feedback can barely bring long-lasting interests. In order to gain the satisfied effects, the complicated structure of TRIZ must be tailored accordingly. Classifying the contents of TRIZ and combining with the corresponding textbook for different audience is one of the important tasks for efficient TRIZ popularization and application.

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Integrated Pathways: Connecting the Disconnected

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SELECT SESSION

C4: The role and impact of engineers and the engineering profession in the wider community

CONTEXT

This paper presents a program that has been developed to provide a pathway for students from secondary school into the New Zealand Diploma of Engineering (NZDE). In New Zealand, the Government has highlighted that there is a deficit of engineers going into industry at level 6 and 7 (Tertiary Education Commission, 2010), which will have a serious impact on NZ productivity in the years to come. To address this issue a NZ ITP and two local Hamilton secondary schools formed a partnership that would provide a meaningful pathway for level 3 students that would allow access to tertiary study and industry beyond.

PURPOSE

This program of study needed to take students who had disconnected with maths and physics and to connect them with engineering concepts in a contextualised manner and to provide them with entry into the NZDE. While the focus of this program was on year 13 students, this program also needed to provide opportunities for target groups such as Maori and Pacifica and Women, to engage with the world of engineering that would enable them to pathway into tertiary study. The first pilot of this program was run in 2016.

APPROACH

To develop this program, it was necessary for teachers from school and Wintec to work closely together to develop a model that would support these aims. To do this we developed a fully integrated 3+2 model, where students would participate in a contextualised program of study for three days at school. To compliment this the students attended Wintec for 2 days and were enrolled in Level 3 Trades Academy courses that would support the teaching at school.

RESULTS

From the first running of the program in 2016, out of the 15 students enrolled from Fairfield College, 9 achieved NCEA level 3 (achieved 80 credits. Out of these students all 9 of these students then enrolled in the NZDE.

One of the offshoot benefits from this program has been the learning and professional development that has come from teachers from both school and ITP moving into each other’s environment to teach. One of the main findings was that many students reported that without the experience and appreciation of the course they would have left school without a clear goal or direction for their future.

CONCLUSIONS

Generally, this program has worked well and has managed to provide a pathway for students into the NZDE. It has also provided some unforeseen benefits.

KEYWORDS

Integrated programme; contextualised learning; 3+2 model

Introduction

In New Zealand, the Government has highlighted that there exists a deficit of engineers going into industry with level 6 and 7 qualifications (Tertiary Education Commission, 2010). This deficit has been highlighted because it will have a serious impact on NZ productivity in the years to come. To address this deficit in engineering graduates Tertiary Education Commission (TEC) developed the Engineering Education 2 Employment (EE2E) campaign (http://engineeringe2e.org.nz/, 2017), to promote engineering careers within schools predominantly. Waikato Institute of Technology (Wintec), and two local Hamilton secondary schools - Fairfield College, and Fraser High School, formed a partnership that would enable level 3 students access to tertiary study through the New Zealand Diploma of Engineering (NZDE) and industry beyond. This paper will focus on the development of this programme, its aims and objectives, from both Wintec and the school's perspectives. It will also look at the first intake onto the programme, the issues that were faced and what has been learnt from them, and how that has shaped the development of the next phase of the programme.

Purpose

In 2010 the National Engineering Education Plan (NEEP) Project put forward a national plan for ensuring that the right numbers of the right types of graduates are produced to meet New Zealand's needs (Tertiary Education Commission, 2010). Table 1 below shows the areas where the NEEP project projected that more graduates would be needed if New Zealand were to be an Innovation led economy.

Table 1: The deficit of engineering Graduates as identified by the NEEP project in 2010

Qualification type	Actual qualifications completed in 2018	Estimated annual needs "business as usual"	Estimated annual needs "innovation led economy"	% growth required
Level 6 NZ Diploma in Engineering Engineering Technicians – 2 year qualification (Dublin Accord)	270	500	750	85% - 178%
Level 7 Bachelor of Engineering Technology Engineering Technologists 3 year qualification (Sydney Accord)	180	400	600	120% - 233%
Level 8 Bachelor of Engineering Professional Engineers 4 year qualification (Washington Accord)	1050	1100	1400	5% - 33%
Total	1500	2000	2750	33% - 83%

To achieve this aim, the Tertiary Education Commission (TEC) developed a working party known as Engineering Education 2 Employment (EE2E). This group were tasked with increasing the number of students entering engineering. Part of the approach used by this group was looking at Secondary Tertiary Partnerships (STP's) which included a range of different options that would bring secondary schools and tertiary institutions together to promote engineering as a career of choice. One of these options is the 3+2 partnership and this is the basis of the Integrated Pathways Programme developed between Wintec and both Fairfield College and Fraser High School.

The 3+2 approaches for secondary / tertiary programmes

The purpose of a 3+2 partnership (3 + 2 days) is to offer greater choice of curriculum for learners in the senior secondary school at Level 3, which are aligned to Vocational Pathways. This diversity can provide a range of pathways because of this multi-partnership approach.

While secondary schools have traditionally done well in preparing those school leavers who move on to degree-level study (around 30% of school leavers), they typically do less well in preparing the remaining 70% of school leavers for further study, training and employment (Ministry of Education, 2016). This latter group of young people have diverse needs. 3+2 approaches are primarily aimed at better meeting the curriculum needs of students who have already turned 16 and who have achieved NCEA Level 2. There are also others likely to benefit

Figures published by Education Counts (2017) using Ministry of Education data, identified that for secondary school leavers in 2015 - 2016:

- 19% left school before completing NCEA Level 2
- 27% of learners completed NCEA Level 2 and left without attempting NCEA Level 3
- 53% of learners completed NCEA Level 2 and went on to gain NCEA Level 3
- 32% of students went on to degree level study

This information indicated that there was an opportunity for 3+2 approaches primarily for the 27% of learners with NCEA Level 2 but leave without completing NCEA Level 3, but who might have stayed if the curriculum offering were different. It is also highly likely that this type of programme would appeal to some of the 19% who leave before NCEA Level 2. It may also appeal to some of the 53% of students who progress to achieving NCEA Level 3; after all, only 32% of these go directly to degree level study on leaving school.

What is also really worth mentioning is that some of the 32% that leave to go into degree level study might also find a mix of school and/or tertiary/work appealing – particularly if careful subject selection and programme planning keep the possibility of gaining a University Entrance award alive.

There are significant benefits for learners who enrol in 3 + 2 approaches. It opens up learning opportunities that cannot be delivered at school or at a tertiary organisation and allows learners to achieve NCEA level 3 while working towards a relevant tertiary qualification.

Involvement in a 3 + 2 programme allows students to also experience tertiary learning while still at school while providing an insight into the wide range of careers and jobs available. This type of programme assists learners with an opportunity to plan their pathway to employment and access relevant leaning to get started.

Wintec's Perspective

Wintec has adopted this 3+2 model of learning with two local high school, Fraser High School and Fairfield college to provide benefits to students and secondary schools while also providing a clear and meaningful pathway for student to transition into tertiary study. This approach when applied to engineering means, that Wintec could have some control over the level and types of maths and physics that these students studied, before they transitioned into the NZDE in either Civil, Electrical or Mechanical Engineering. This has been a significant issue in the past and has contributed to disengagement and retention issues with maths at this level.

Fairfield Colleges' Perspective

Fairfield College saw this as an exciting opportunity to connect our students to an engineering pathway that offers significant career prospects. It was a compelling proposition to create purpose and context in learning, with a clearer line of sight between what a student learns at school and how it is connected to an engineering vocational pathway.

As a secondary school, we saw this as a means of retaining students in secondary school education as some of these students would have otherwise left during the year. It provided students with an opportunity to re-engage with science, while giving them a level 3 qualification and a career pathway at the same time. The programme was envisaged to act as a type of springboard for students towards studying at level 5 or level 6 once they left secondary school.

Fairfield College deliberately restricted entry into this programme to year 13 students because we viewed the NCEA Level 3 qualification as the school exit qualification that we were supporting students to achieve rather than a level 2 qualification. We promoted the view that this year was not the final year of secondary school, but the first year of a three-year programme that placed our students in the strongest possible position to pursue tertiary studies with a particular focus towards enrolling at Wintec and studying for the NZ Diploma of Engineering (NZDE). This programme enabled us to strengthen our learning relationship with the tertiary institution and gave our school an opportunity to contribute to an area of national need. The programme was developed to include the following:

- Engineering Science was a requirement. In this the students studied Mathematics and Physics, which was contextualised to Engineering and was developed with the two institutions working together. A lot of the teaching of the Physics and Mathematics concepts were through practical projects.
- Effective Oral and Written Communication was offered as this was needed for any career of our students' choice.
- Healthy Living, was made up of cooking, food and nutrition and physical activity. The reasoning behind including this course of study here was that these are the life skills needed by young adults.
- Developing Career Competencies had a strong focus on career education and soft skills. Students developed their CVs and learnt interview skills with the help of the career navigator programme developed through the Graeme Dingle Foundation and the 'Grow' programme from Deloitte. During some of the sessions in this class engineers were invited into class to give motivational talks to the students to maintain focus and enthusiasm in engineering.

Development of the Integrated programme

To develop this program, it was necessary for teachers from school and Wintec to work closely together to develop a model that would include the different components of the programme mentioned above. To achieve this, regular meetings were arranged between tutors at Wintec and School that allowed the development of a fully integrated 3+2 curriculum - where students would participate in a contextualised program of study for three days at school and 2 days at Wintec. It was important that we developed the school based programme so that it was aligned with the work that students would be engaged in at Wintec. At school, this learning in combination with the fact the students would be out of school for two days, resulted in the decision to set the programme as a stand-alone course that operated independently from the normal school timetable. The objective from the school's point of view was to develop a programme that would deliver engineering competencies, as well as support more holistic growth in the students. An example timetable and summary of content is provided in Table 2 below.

Table 2. The timetable for the Integrated Pathways students in 2016 (Fairfield College).

Period	Monday	Tuesday	Wednesday	Thursday	Friday
1	8.40 (1) Effective Oral and Written Communication	9.00 study class	WINTEC	WINTEC	8.40 (2) Developing Career Competencies
Whanau	9.40 Whanau				9.40 Whanau
2	10.00 (2) Effective Oral and Written Communication	9.50 (6) Engineering Science			10.00 (3) Developing Career Competencies
Lunch 1	11.00	10.45			11.00
3	11.35 (3) Engineering Science	11.20 (1) Healthy Living			11.35 (4) Engineering Science
4	12.35 (4) Engineering Science	12.45 (2) Healthy Living			12.35 (5) Engineering Science
Lunch 2	1.35	1.35			1.35
5	2.10 (5) Healthy Living	2.10 (3) Engineering Science			2.10 (6) Effective Oral and Written Communication
	3.10	3.10			3.10

During the three days at school the students would study Engineering science (Maths and Physics), Communications, Physical Education and Health Science. The Engineering Science component was developed from the NCEA level 2 Achievement standards for Maths and Physics, which were suitable for entry into the NZDE in Engineering at Wintec. Tables 3 and 4 over the page, shows the list of Maths and Physics achievement standards that would be taught in school. With these standards in mind teaching activities were selected that would enable the students to explore engineering concepts from the three engineering disciplines, Civil, Mechanical and Electrical Engineering.

These activities were designed to engage the students with the maths and physics required to support the concept, all the while making sure that the requirements of the Achievement standards were being met. A typical example was the design and build of bridges. This activity included research into different bridge designs which also looked at the maths and physics associated with each design. The students then had to build a bridge to fit a specific criterion and then test them. The students' knowledge of these discipline areas was tested at the end of each term.

To compliment this programme of work the students attended Wintec for 2 days and were enrolled in two Level 3 Trades Academy courses in Mechanical Engineering (Semester 1) and then Building and Construction (Semester 2). These courses were chosen because:

Table 3. Maths Achievement standards being taught at school

Maths Core compulsory must be taught				
Unit	Title	Credits	Level	Exams
91259	Apply trigonometric relationships in solving problems	3	2	Internal
91261	Apply algebraic methods in solving problems	4	2	External
91262	Apply calculus methods in solving problems	5	2	External
Compulsory with less emphasis				
91269	Apply systems of equations in solving problems	2	2	Internal
Optional/ Extended				
91257	Applied graphical methods in solving problems	4	2	Internal

Table 4. Physics Achievement standards being taught at school

Physics Core compulsory must be taught				
		Credits	Level	Exams
91171	Demonstrate understanding of mechanics	6	2	External
91173	Demonstrate understanding of electricity and electromagnetism	6	2	External
91169	Demonstrate understanding of physics relevant to a selected context	3	2	Internal

1. they would complement the teaching at school;
2. they were courses that Wintec already delivered and that the students could access with their current skill levels; and
3. They would be able to achieve NCEA level 3 credits through these Unit standards.

Tables 5 and 6 below show the list of Unit standards that the students studied on this programme. The Achievement standards mentioned in tables 3 & 4 above and the Unit standards in tables 5 & 6 below, refer to discrete pockets of learning around a specific topic. The credit level gives an indication of the amount of work required with one credit equating to 10 hours of study. The standards can be either level 1,2 or 3, and an approved programme of Unit standards can lead to a qualification, while the Achievement standards lead to NCEA level 1, 2 or 3.

This teaching was supported by site visits in a range of different engineering disciplines such as to a visit to Glenbrook Steel Mill to talk about Materials and materials testing, and also a visit to Huntly Power station. Guest lectures were also arranged with engineers coming in to talk about what they did in the real world. A very good example of this was a visit by a young Civil Engineering (Wintec) graduate working with MWH who talked to the students about his background and studies and provided some really interesting examples of the modelling he uses for road design.

Table 5. Mechanical Engineering Unit Standards

Unit Standard	Title	Credit	Level
25075	Perform basic fabrication operations under supervision	12	2
4797	Demonstrate knowledge of the composition of engineering materials	5	3
21910	Interpret mechanical engineering drawings	5	3
10 credits available out of the possible 20 credits listed below			
22908	Demonstrate and apply knowledge of manually controlled machining operations	10	3
2677	TiG Welding	6	3
2683	Thermal cutting	4	3
	Total NZQA Credits	32	

Table 6. Building and Construction Unit Standards

Unit Standard	Title	Credit	Level
12998	Demonstrate knowledge of carpentry hand tools.	4	3
12999	knowledge of timber machining equipment	3	3
13037	Safely use and maintain carpentry hand tools on site.	6	3
13038	Safely use and maintain bench saws	2	3
24378	Perform building calculations.	4	3
24381	Knowledge of floor framing and flooring construction.	3	3
24401	Install thermal insulation materials in buildings on site	1	3
13032	Non-mechanical, Mechanical Construction Equipment	1	3
16407	Use and maintain hand and power tools for electrical work	4	3
	Total NZQA Credits	**28**	

During the running of the program all institutions worked closely together providing ongoing support to ensure that delivery aligned to provide the best possible learning experience for the students. To determine how well this program of study was progressing, a framework of data collection was wrapped around the program. Data was collected via a range of different mechanisms both at school and at Wintec. At school discussions between the students and teachers occurred throughout the week, the information from which was fed into weekly sessions at Wintec. Aligned with this every 6 weeks all tutors would meet to discuss student progress, and to ensure that the students were receiving adequate academic and pastoral support.

As well as the 6 weekly meetings at Wintec data on student progress while at Wintec was gathered using a variety of different mechanisms, including in class feedback, student forum sessions, and assessment marks. As well monthly progress reports were compiled and sent to schools and parents to keep them informed of the students' progress. This also allowed for intervention strategies as required. As the program drew to its conclusion a survey of the students was also conducted. The aim of this survey was to determine why the students engaged with the program, what they thought they had got out of it and also where they believed it was taking them.

Results

Out of the 15 students enrolled from Fairfield College in 2016, 13 students achieved all or some of the 48 credits available at NCEA level 3 from the Mechanical Engineering and Building and construction courses at Wintec. Out of these students, 9 were eligible to enrol in the Mechanical NZDE. The remaining 4 progressed out into employment.

Feedback provided by the students from the initial survey suggests that they were better prepared for study at tertiary level and were more confident in their understanding of practical and project based approaches to teaching. The students also mentioned that because of their involvement with the Integrated Pathways programme they believed they were more informed of the potential engineering pathways available to them in engineering. They also believed that they could make more informed choices about their future study and career pathways. However, the students also mentioned that they had been influenced in their choice of engineering discipline through their exposure to the practical engineering courses they had studied first in Trades Academy, rather than the site visits and guest speakers. Hence all the students from Fairfield College enrolled into the Mechanical NZDE.

Discussion

From the conversion rate of students into the NZDE this programme could be deemed a success, the disconnected had been connected. However, this is only from one school, this conversion rate did not translate to Fraser High School. A major issue faced by both institutions was the selection of the students for the Integrated Pathways Programme. For Fairfield College, the aim of the programme was to provide an alternative way for some of their students to achieve NCEA level 3. For Fraser High School it was more about providing their students with exposure to engineering career pathways, while many of their students were already enrolled in and were studying towards NCEA level 3. This provided 2 cohorts of very different students coming into Wintec. However, the aim for Wintec was for a cohort of students who would be better prepared and equipped for entry into the NZDE, and as all parties were working towards a common goal it was possible to provide modifications to the programme, generally within the school, that would complement each cohort.

While the idea of the programme worked well in theory, some of the realities of the contexts in which we work provided several significant obstacles, for example issues with funding when moving between secondary and tertiary environments. In NZ, secondary funding is governed by the Ministry of Education (MOE) while tertiary funding is overseen by the Tertiary Education Commission (TEC). Therefore, for funding of the programme, there were significant hoops to jump through which needed to satisfy either one or both funding bodies. Another major issue was time-tabling of activities between the various institutions, this proved to be quite challenging but the constant communication amongst the team enabled the re-arrangement of classes to accommodate most timetable changes and issues.

While we have focussed on some of the issues, there have been a number of unforeseen benefits to all the institutions involved – one of these comes in the form of the learning and professional development that has come from teachers from both schools and ITP moving into each other's environment to teach. This has provided significant benefit in providing linkages for the students between their theory and practice, and in improving teaching practice in both institutions

For the students, a significant learning was how influenced they were by the first Trades Academy programme that they studied. This means that going forward the programme design needs to ensure that the students have equal exposure to the three main engineering disciplines so that they could make a qualified choice on their field of study. As can be seen from the numbers who enrolled into Mechanical Engineering this was not the case for this particular cohort.

Conclusions

Overall this programme has been a success and both schools have moved into a second year of the programme. The partnership has used the learnings from the pilot in 2016 to implement changes and move the programme forward, to enhance the students' experience and learning opportunities within engineering.

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Running an Open MOOC on Learning in Laboratories

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CONTEXT Teaching in laboratories plays an integral role in education. This includes both proximal as well as remote laboratories. In many instances, learning activities are designed around equipment and traditional laboratory activities. Pedagogical aspects and instructional design are often not considered or are an afterthought.

PURPOSE The aim of this project was to help to address this gap by designing, implementing and facilitating an open online course on the pedagogy of using laboratory experiences in the curriculum.

APPROACH The MOOC for Enhancing Laboratory Learning Outcomes (MELLO) has been designed to assist educators at all levels, from schools to universities, to improve the quality of laboratory experiences in STEM (Science, Technology, Engineering, and Mathematics) education. Experienced educators seeking to review and revise current practices or beginning educators were all welcome to participate. Based on learning theory and research literature, online course has been developed that covers constructive alignment of practical activities with the wider curriculum, learning objectives, pedagogical approaches to laboratory learning, laboratory modalities and session planning.

RESULTS 120 participants from Australia and around the world took part in the course. While the participants did not work on their own laboratory activity throughout the courses (as envisaged when designing the course), participants who actively took part in the course were positive about the value of the course.

CONCLUSIONS The MOOC has been capable of supporting a large number of participants including university educators around the world who use laboratory experiences and will continue to do so through future iterations of the course. Moving forward, there is scope to adapt the pedagogical approach of the course to cater for the way the participants have engaged with the material.

KEYWORDS laboratory teaching, practical learning activities, MOOC

Introduction

When designing learning activities, one of the key focus questions is: What do we want the students to be able to do when they have completed the activities? In the context of practice-based disciplines such as Engineering and Sciences, this often includes practical tasks. Such skills are traditionally taught in laboratory classes and these are often favourites of students as they provide tangible ways to apply theoretical concepts.

Technological developments in the last two decades have enabled new approaches for teaching through laboratories These include remote laboratories (Maiti, Maxwell, & Kist, 2014), virtual laboratories (Nedic, Machotka, & Nafalski, 2003) as well as augmented reality in labs (Andujar, Mejías, & Marquez, 2011). These allow access to hardware or virtual experiments remotely via the Internet but come with a range of pedagogical issues which need to be tackled for optimal implementation.

Learning and teaching is being widely addressed for academic classes, through learning and teaching support units, for example. There is also a strong focus on articulated learning outcomes by Australian Higher Education Standards Framework (Birmingham, 2015) and professional accreditation bodies such as Engineers Australia. However, this focus often does not translate to pedagogical approaches to teaching in laboratories.

Anecdotal evidence suggests that many laboratory activities are not outcomes of critical evaluation and course design; they are often products of tradition, availability of equipment, personal exposure and preferences of academics involved.

An OLT project on adaptive learning guides (Lowe, Murray, Lindsay, & Bharathy, 2014) has also identified this shortfall, both in the literature review of the project report as well as the evaluators comments. Appendix C p. 3-4 states that “...there has been less attention to the pedagogic issues involved in providing skeleton lesson plans. This is a potentially interesting direction for future work in the area.”

The Massive Open Online Course (MOOC) for Enhancing Laboratory Learning Outcomes (MELLO), disused in this paper is an attempt to address this gap. The remainder of the paper briefly introduces the underlying educational framework followed by a section that outlines the course design. Sections on data collection, findings and observations conclude the paper.

Educational Framework

The content that is presented in MELLO is based on key literature in the field. Main sources that have informed the content development include fundamental objectives of Engineering instructional laboratories (Feisel & Rosa, 2005) and generic aims for traditional Science laboratory learning (Johnstone & Al-Shuaili, 2001). These are linked to learning activities in laboratories through the principle of constructive alignment (Biggs & Tang, 2007). For example, White’s (1996) description of how “laboratory” learning can be conceived of as an instance in which the learner experiences learning “episodes¨ has been explored as this places a greater focus on learning objectives, activities and outcomes instead of equipment, as is often the case in discussions of laboratory tasks.

Laboratories can be classified as expository, inquiry, discovery, and problem-based (Johnstone & Al-Shuaili, 2001). This approach helps to better understand condition for learning, laboratories present and helps to unpack associated aims, outcomes, approaches and procedures. Generally speaking, teachers can support the development of appropriate learner behaviours by designing lessons and scaffolding learning according to the conditions for learning that are appropriate to the lab type (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989, pp. 53-64).

Course Design

This course has taken an educational rather than a technical focus on the design of labs. It therefore covers a set of key educational issues for the effective design of labs, including:

- Constructive alignment between labs and other aspects of curriculum
- Design and selection of achievable learning objectives
- Selection and implementation of an appropriate pedagogical approach to labs – matched to the learning objectives that have been set (for example, expository, discovery or problem-based)
- Selection of appropriate lab modality (e.g. face to face, versus remote, versus simulated)
- Planning and preparing lab sessions for enhanced learning

Participants in the course have a degree of choice over how they participate. At the most basic level, the course provides a series of lectures, videos and resources as stimuli for participants to begin considering how labs should be designed in order to be educationally effective. These materials form the core of the course upon which other optional activities can be built. In addition to these materials, a number of planning and design activities are suggested for participants to undertake individually in order to progress their own instructional design knowledge and experience. As such, the course has an organizing and critically reflective function not available to teachers simply searching for available information about labs.

Course Learning Outcomes

The main course outcomes can be summarised as follows: By the end of the course, participants will be able to

- contrast how laboratory activities are used in different disciplines and identify parallels to your own laboratory learning activities,
- draw a map of how the learning activities in your lab are aligned,
- evaluate different types of laboratories, learning opportunities they present and apply the insights to your context,
- develop activity guides and lesson plans based on sound pedagogical principles.

Modes of Participation

MOOCs come with various degrees of social interaction and levels of commitment by participants. To cater for a broad spectrum, MELLO has supported two modes of participation, a connectivist MOOC (cMOOC) focusing on a mix of self-directed and social learning; and an xMOOC that provides open access to learning materials. The cMOOC has used an Action Learning approach based on the model developed by Revans (2011) that uses an iterative process of “Explore - Plan - Act - Reflect”. In contrast, the xMOOC supports self-paced participation with access to the content created for the “Explore” component of the cMOOC and discussion forums.

The x-mode is intended to engage individuals who want quick access to the content, structure and activities of the course, but are unwilling or unable to commit to regular meetings, sharing, and the timelines of the Action Learning Cycle. The benefit of the course in the xMOOC mode is that it helps participants to access key materials and organize and think about the materials and their implications in a way that conducting their own search of the literature would not do (or would take much more time to do). In this view, the course provides structure to the key theory, research and examples in the laboratory learning field, thus improving access to the field for participants.

Platform Used for the Course

There are a number of large open learning platforms available, such as Coursera, Ed-X, Udacity, Canvas Network and Open Learning. Given that the project operated on a small budged and that home institution is not affiliated with any of the larger providers, finding a suitable platform proved to be a challenge. The other difficulty was around requirements of copyright and content ownership. These issues caused some significant delays and ultimately required the rescheduling of the course start.

The constraints included a platform that allows fee access to the course. Ultimately an agreement was reached that satisfied the requirement of the funding body, the institution's legal requirements and the need to access to appropriate facilities to deliver the course. In the end, operational factors outweighed considerations for educational features. OpenLearning was used as a platform to offer MELLO, which generally worked well for the xMOOC component of the course.

Course Structure

Typical modules in the course consist of web-based, multimedia & text-based study materials. Brief expert videos and webinars provide stimulus material about key concepts. Virtual tours provide a window into labs in use. These components are combined with activities, contributions by participants and further reading. The main modules are:

Module 1 - Developing laboratory classes for the digital age

Module 2 – Developing the aims, objectives and alignment of laboratory classes

Module 3 - Types of labs and the conditions for learning they present

Module 4 – Structuring and Supporting Learning in Laboratory Classes

Module 5 - Modern Laboratory Learning Environments

Module 6 - Bringing it all together - developing activity guides and lesson plans

Data Collection

In order to assess the value, relevance and significance of the course, data was collected from participants in three ways. As a part of the course activities (subject to explicit consent) students in the course completed both entry and exit surveys in order to both analyse their own needs and goals, and to gather information about their reasons for participation, their expectations and perceptions of the course. This data helps in the interpretation of discussion data that was collected during the course from students engaged in course activities within the open learning platform. This data gives insights into how students were responding to specific issues within the course, and therefore whether the course was meeting its aims.

Observations

Whilst 120 students participated in the course, there was a smaller group who actively contributed to discussions. As is common in MOOC courses, significant attrition was apparent as the course progressed. It should be noted that such attrition is not necessarily indicative of the value or effectiveness of the course, because it is not known what the goals or expectations of departing students were if they did not complete an entry survey. For example, if their goal was to access specific information for their own needs, the course satisfying this goal may be the reason for their early departure. Such an instance would mean the course was successful rather than the opposite.

Participation Over Time

Figure 1 shows student comments (in discussion topics) over time. The graph suggests that the early interest in the course was high and that this was supported by the high level of activity within the cohort.

That is, it is more interesting and rewarding to engage in discussion when there are many others also doing so. It should be noted that not all students joined the course at the same time, which is why the spread of comments does not coincide with the ten-week period around which the course is designed.

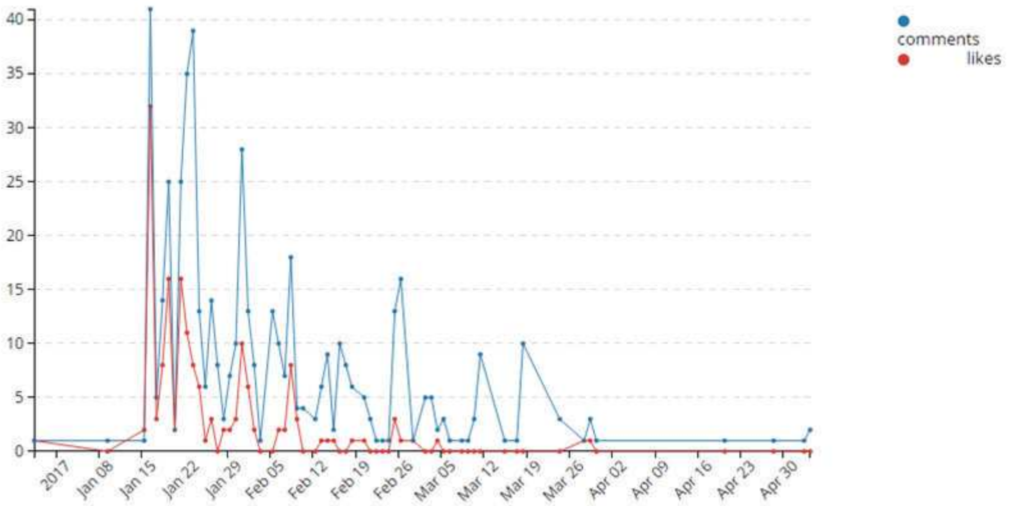

Figure 1 Figure 1 - Number of participant comments and likes over time

Participants’ Motivation

First, it is necessary to note some findings from the entry and exit surveys concerning participants´ reasons for participation. In total, 24 participants completed the voluntary entry survey, and seven completed the exit survey. Whilst this appears to be a high level of attrition, the research literature shows this to be normal in MOOCs (e.g., Gütl, Rizzardini, Chang, & Morales, 2014).

The entry survey asked participants their reasons for taking part in the course. Of the 24 responding participants, it is noteworthy that only five of these cited specific pedagogical goals and two specific curricular goals. Their specific comments are as follows:

Specific pedagogical goals:

- I work in educational development in STEM. I would like to learn more about lab teaching in a global perspective and am curious to see how a MOOC on lab teaching can be organized.
- I am working to modernize our labs and want a fresh perspective of how labs are offered elsewhere and get insight into the advances in delivering labs.
- Working as a young assistant professor in a technical university implies, in general, teaching applications for different disciplines. In my case, most of these applications consist in practical lessons conducted inside lab sessions. For this reason, I continuously try to develop my teaching skills and the way I organize my laboratory classes in order to improve the learning activities I conduct during these classes and I

am confident that this course will help me to make a step forward in achieving this objective.

- We are in the process of revamping a number of our lab courses and it seemed like this course would give me food for thought.
- How to design a pedagogical efficient lab activity.

Specific curricular goals:

- Because I am working on the development of remote laboratories in the electronics field.
- I am looking for ways to improve the practical part of the courses I teach.

Only some of these goals relate to the development or improvement of specific laboratory activities. The remainder of the participants´ comments concerning their reasons for taking part were seen to be either general pedagogical goals or general learning goals (10 and 7 instances respectively). For instance, some participants cited "curiosity", wanting to improve their teaching in a general way or "to get the best for my students." Whilst these are all valid aims, they do not necessarily coincide with an ability among participants to undertake the specific lab design activities that were suggested in the course. Similarly, comments about expectations about and desired outcomes of the course show that many participants had not formed a clear idea of what they would get from the course. This may explain why no participants showcased a revised lab activity at the end of the course.

Notwithstanding these findings, the other comments from the entry and exit surveys are uniformly positive about participants´ value for the course. Of the seven participants who completed the exit survey, three agreed and four strongly agreed that the course had helped them to think effectively about what laboratory teaching entails, and four agreed and three strongly agreed the course had helped them to think about what laboratory learning means for their students.

Action Learning Participation

Of the one hundred and twenty participants in the MOOC, only four (3.3%) registered interest in participating in the Action Learning mode. Of these only two completed that process by forming a learning set and participating in the online meetings and creating a project. Both responded to the exit survey with one agreeing and the other strongly agreeing that the Action Learning cycles were successful in engaging them in this MOOC.

There were a number of challenges when preparing to conduct Action Learning in the context of a MOOC. Firstly, Action Learning is not a commonly used professional learning strategy in MOOCs. No evidence of conducting a MOOC using a formal Action Learning process as the pedagogical approach was found in the literature prior to this attempt. The novelty and unfamiliarity of the approach may have impacted willingness to participate in this mode.

Secondly, the technical capability of this and other MOOC platforms limits the ability for participants to find other participants in compatible time zones to form learning sets. The lack of a suitable tool for self-matching meant that Action Learners had to register and then wait to be matched with potential Learning Set members using tools outside the MOOC platform. This challenge was compounded by the staggered starting dates of many participants. One participant who requested to engage in an Action Learning mode joined the course four weeks after the beginning of the program and as a result, there was no one to match them with. Another potential Action Learner never responded to the internal messages in the system to complete the matching process.

A dedicated tool for matching participants to form Action Learning Sets in MOOCs would solve this problem. The features would need to include the attributes of the individuals that would allow matching. This could include time zone, days and times available for Learning Set meetings, languages spoken, email address, and platform for web-conferencing.

Thirdly, Action Learning Sets, the small groups who meet periodically through the course, usually meet synchronously. In online programs, this means they need to use tools such as text chat, audio chat, virtual worlds or web-conferencing. This adds a requirement for a level technical expertise not required in the self-paced mode which simply involves clicking on links on web pages, viewing videos and typing comments. This may have been another barrier to selecting Action Learning as a mode of engagement with the MOOC.

Relevant Pedagogies for Laboratory Learning

Concerning whether the MOOC had given them strategies for identifying appropriate pedagogies for use in their lab and whether it gave them the chance to share and explore explicit strategies for improving lab learning, and how the strategies could be introduced to their teaching, the results were more equivocal:

The MOOC gave me strategies for identifying appropriate pedagogies for use in my lab					
Neutral	2	Agree	**1**	Strongly agree	3
The MOOC gave me the chance to share and explore explicit strategies for improving laboratory learning in my students					
Neutral	2	Agree	**4**	Strongly agree	1
I can see how at least some of the strategies can be introduced to my teaching					
Neutral	3	Agree	**1**	Strongly agree	3

Table 1 - Exit survey responses about specific pedagogical strategies

Here, the neutral responses may relate to participants´ lack of a specific lab activity to relate the teaching development to.

As was seen above, discussion in the course was higher in volume in the early stages of participation, and facilitators participated in this discussion to try to promote in-depth discussion of the activity questions that were provided. However, although contribution to discussion was frequent and at times thoughtful and insightful, especially during the first two modules, participants did not often comment on one topic more than once, thereby limiting the depth of discussion. Where the facilitator participated in discussion posts with feedback or requests for more information, this was often not responded to, or a superficial level of thought was given to the prompt

The course (especially the activity prompts that were provided) intended that participants would reach a greater degree of discussion and reflection on the issues being discussed. However, this degree of discussion may not be achievable in asynchronous forums, and may better lend itself to synchronous sessions, such as the action learning groups. This may be tested in future iterations of the course, with greater numbers of participants actively contributing in each access mode.

A number of strategies are available that may assist with this. First, recruitment of participants into the course should better emphasise that the course is most effective for participants who have a specific laboratory learning experience in mind or that is relevant to their context to be used as an example or a tool for thinking about the issues with. Without this, some of the fundamental problems highlighted throughout the course, such as a tendency to design for students to complete a task instead of designing for students to learn something specific, do not become clear to participants. Second, with ongoing and increasing participation in the course, a community of inquiry may be built in which existing participants may continue to take part in discussion around core issues. This kind of critical mass would allow for the improvement of both volume and depth of discussion.

Conclusions

The course has supported educators form a range of disciplines including Engineering, Sciences, Health Sciences, ICT and Teacher Education. Participants included university educators as well as Secondary School Science teachers. This led to more diverse interactions on laboratory experiences in learning and teaching. The project has developed resources that will remain available. It has enabled systematic and broad opportunistic adoption of best practices in the use of laboratory experiences in learning and teaching at universities and in schools. While most participants have not engaged with the courses in the way it was originally designed, the participants were very positive about the course and the content.

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STEAMpunk Girls Co-Design: Exploring a more Integrated Approach to STEM Engagement for Young Women

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SESSION S1: Is Integrated Engineering Education Necessary?

CONTEXT

The call to increase the capacity of Australia's STEM workforce has resulted in a spotlight on the comparably fewer number of women working in STEM. One strategy to address this lack of representation is an integrated, 'STEAM' approach to teaching and learning STEM. STEAM education recognises the role of arts/humanities and the potential utility of a more creative mindset, applied to learning and teaching STEM. Whilst STEAM is still a relatively new pedagogical approach, research suggests positive outcomes whereby young people can develop innovative and transdisciplinary skillsets that can enhance their employment prospects in disciplines such as engineering.

PURPOSE

The STEAMpunk Girls Co-Design program aims to determine if an integrated approach to education across the science, technology, engineering, arts and maths (STEAM) fields, can promote stronger engagement and a sense of empowerment, confidence and agency among young women in terms of their willingness to pursue STEM study and careers.

APPROACH

A 10-day program was conducted in November 2016, involved 26 girls (aged 15–16 years) from three Sydney high schools. Students were enlisted to design a STEAM-based educational pilot for their peers. Longitudinal data was collected from online pre- and post-program surveys.

RESULTS

Findings reveal a unique, female perspective that can utilised to improve STEM engagement programs for their peers (particularly if such programs seek to integrate the arts, humanities and social sciences as a means of increasing interest, engagement and retention in STEM). Students reported improvements in their understanding of the types of work people undertake in science, technology, engineering, and arts industries, as well as the variety of cross-disciplinary skills needed to work in STEM industries. Co-design proved to be a fitting methodological framework for the participants to experience a safe and supportive environment to experiment and trial their ideas. Program feedback was predominantly positive, with an average satisfaction agreement rating of 92% across all feedback categories.

CONCLUSIONS

The STEAMpunk Girls co-design program identified benefits STEM-Arts integration, as well as issues and obstacles that adversely affect young women's engagement in STEM fields such as engineering.

KEYWORDS

STEM, STEAM, gender, co-design

Introduction

In Australia, STEM (Science, Technology, Engineering and Maths) knowledge is recognised as an important aspect of the fastest growing occupations and innovations. Despite this, interest and enrolment in STEM subjects appears to be on the decline among Australian students (Kennedy, Lyons & Quinn, 2014; Pricewaterhousecoopers, 2015). The call to increase the capacity of Australian students' STEM engagement has resulted in a spotlight on the comparably fewer number of women, in particular, enrolling in STEM programs, and working in STEM industries (Blickenstaff, 2005; Broadley, 2015; Greenfield et al., 2002). Early research suggests that academic attainment presents obstacles for women to enter STEM programs (e.g., Raffe et al., 2006). Other research suggests it is women's differing interest and motivations (Smith 2011), and their perceptions of self-efficacy in STEM fields (Falk et al., 2016; Nye et al., 2012; Valla & Cecil, 2014) that influences the numbers of women in STEM. Arising from and contributing to these factors are environmental, social, cultural, political and institutional factors (Ceci et al., 2009; Phipps, 2002; Smith 2011; Terzian, 2006) with the finding that certain STEM fields are perceived by women as being less welcoming or even hostile environments (MIT, 1999; Sonnert et al., 2007).

Harkening back to earlier studies examining attainment, Wang, Eccles and Kenny (2013) found that aptitude in maths and corresponding lesser aptitude in verbal/communicative fields was an influencing factor in students' decision to pursue a STEM career. Among students with strong quantitative aptitudes, the authors reported that women were more likely than men to possess symmetrical aptitude tendencies, i.e., women had a strong aptitude in both quantitative areas *and* verbal/communicative areas. Thus arises the contention that an additional explanation for women's underrepresentation in STEM is because women with high STEM aptitudes may be presented with more choice regarding their prospective careers. Whereas for men with strong academic aptitudes in quantitative areas, the options are narrower and/or clearer due to their more asymmetrical aptitude profile. Valla and Cecil (2014) refer to this as the 'breadth based' model of female underrepresentation in STEM. When considering this complex ecology of factors, there is not likely to be a single 'silver bullet' intervention. A common approach at the K-12 level has typically been to address girls' and women's' attainment gaps, and to increase confidence and exposure to STEM. Building on this approach, STEAM education is a relatively new intervention that has shown promise in its capacity to address a wider array of influencing factors. This paper presents findings from the STEAMpunk Girls Co-Design program that has utilised STEAM education to engage young women in STEM.

STEAM

STEAM stands for Science, Information Technology, Engineering, Arts (including creative arts, the social sciences and the humanities) and Maths (Miller & Knezek, 2013). It may be defined conceptually as the integration of its constituent disciplines within a broader philosophy or way of thinking and doing that also incorporates creativity and innovation. Originating in the US, STEAM is a movement that has gradually gained momentum since 2010 (Ellis, 2016). Though there is variation in STEAM approaches, at its heart is the understanding and application of social and human contexts related to issues. Operationally, STEAM can manifest in learning and teaching approaches, through educational institution policy and practice (e.g. curriculum and assessment design), and through organisational culture in workplaces (e.g., in recruitment, professional development, and human resources policies). The benefits of the STEAM philosophy have been espoused both internationally (Care & Luo, 2016), and locally (Barr et al., 2008), with many countries looking to integrate 'transversal' competencies into their education systems.

Though of potential benefit to all STEM fields, STEAM approaches may be of particular utility in engineering due to the field's susceptibility to changes in technology, the economy, the environment, and the attendant, evolving needs of clients and the community. Savage, Chen and Vanasupa (2007) recommend that educational institutions should enable students to become versatile “global engineers”. The attributes of a global engineer include versatility and multi-disciplinary thinking, the ability to adopt a more holistic approach to problem-solving, effective communication skills, the ability to work with different people in diverse setting, and to demonstrate social awareness and responsibility (Miller & Knezek, 2013). STEAM pedagogy can contribute to achieving these objectives through its emphasis on constructivist, student-centric, creative approaches that emphasise a social or human context inherent to many, if not most, problem issues. In terms of engineering pedagogy, Connor, Karmokar & Whittington (2015) refer to the dominant instruction method in engineering as being ‘chalk and talk’ and support a more inquiry based approach borrowed from arts-based pedagogies. When applied to STEM learning, STEAM education also has potential to appeal to a wider variety of learners beyond merely the STEM-inclined (Ahn & Kwon, 2013)

The STEAMpunk Girls Co-Design Program

The co-design program was conducted across eleven days in November 2016. The aim of the program was to empower young women by positioning them as experts on how they wanted to engage with STEM and STEAM, and to provide them with a platform to design a learning experience that the project team could subsequently pilot. Co-design was selected as a particularly suitable methodology. It enables an atmosphere of collective creativity by placing the design process in the hands of the people who gain value from the outcome (Sanders & Simons, 2009).

Twenty-six female students aged 15-16 years from three Sydney high schools attended a full day workshop at a Sydney university where they learned about STEAM (through case studies and meeting STEAM practitioners), design thinking, and empathy. They then spent the following nine days interviewing peers on the topic of engaging young women in STEM and STEAM, using questions of their own design. Each participant was provided with a diary to take notes and reflect on their gleanings. Participants returned to the University for a second workshop to engage in further design thinking through unpacking their interviews and identifying key insights. They worked in teams to apply their new knowledge to prototyping their vision of a STEAM school of the future. To assist this creative process, students were provided with craft materials to create their (‘low-fi’) prototypes.

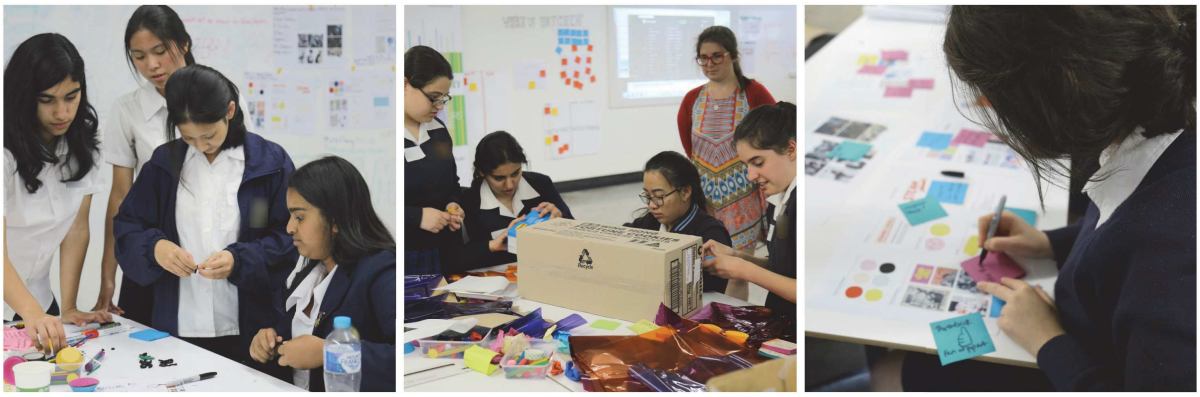

Image 1: Students’ participating in the co-design phase of the program

Data was collected through pre- and post-program online student surveys. The aim of this was to assess changes in student perceptions of self-efficacy relating to the STEAM disciplines, and to ascertain learning preferences and attitudes regarding future study and work. Descriptive statistical analysis was undertaken using Microsoft Excel 2016. Correlational statistics was not undertaken due to the small sample sizes. The participating schools were selected based on existing relationships with UTS and the ability of teachers to devote adequate time to support and lead the program in their schools. A convenience sampling method was used to recruit participants with teachers asked to identify students at their schools who were likely to be interested in participating. All students had parent/ guardian consent to participate in the research and have their photographs used by UTS.

Results

Demographic information

Twenty-five participants (from three schools) took part in the pre-program survey, while 21 students took part in the post-program survey. At the start of the program (n=25), there were 11 girls (44%) were aged 15 years, 13 girls (52%) were aged 16 years (50%), and 1 girl (4%) was aged 17 years. Half of the participants were born in Australia, while more than 73% of students had at least one parent who was born overseas in predominantly Asian countries. Nearly an equal number of students spoke mainly English at home, or another language. Most mothers (77%) and fathers (81%) had completed a university course.

Subject and learning preferences

The overwhelming majority of students agreed that it was important for them to study Maths (92%), Science (85%), and Technology (77%). Most students listed science, maths and IT as being their favourite subjects. Interestingly, there were two new subject areas/themes evident in the post-program survey responses. Engineering was a new subject area mentioned by one student in the post-program responses. Additionally, four students mentioned that they enjoyed a mix of subjects, with some explaining that it was the integration of certain subjects that they found appealing.

[I] like engineering because it has a lot of hands-on activities and not much homework – 15-year old, post-program survey participant

In terms of learning preferences averaged across pre- and post-program survey responses, students reported a strong preference for (in order of preference): learning facts, learning by doing, solving problems, applying learning in the real-world, making models, experimentation, and teamwork. Students also ascribed greater importance in studying maths, science and technology, ahead of arts. Students' self-rated confidence levels (averaged across pre- and post-program surveys) showed higher levels of agreement in relation to confidence in Science (81%) and Arts (71%), and comparatively lower levels of agreement relating to confidence in Maths (69%) and IT (61%). Nevertheless, all the students agreed that they were confident they could do whatever they set their mind to.

Future study and career plans

All the students agreed that they would like to attend university, and the majority in the pre (88%) and post-program survey (90%) agreed that there was a link between STEM subjects and their future career plans. When asked about the types of jobs students preferred, their responses mostly fell within fell within the Sciences and Health Sciences fields (e.g. dentistry, medical research, medicine, optometry, nursing, pharmacist). Remaining responses were distributed (in order of preference) across IT, Creative Arts, Law, Arts/Humanities, Engineering, Media/Communications, Architecture and Building, and Music. The most common explanation was that students expressed a strong interest, aptitude or passion for the disciplines/topics. The students also expressed their desire to do something that could benefit the community.

I enjoy Medical sonography or radiography because I truly do love helping people. This job gives me satisfaction and life fulfilment because it makes me a part of something great, which is helping to save people's lives. In addition to other radiology modalities, the images taken help to diagnosis, treat, and cure many people with diseases or life threatening illnesses which I found very interesting – 16-year old post-program survey participant

Sixty-two percent indicated that they were interested in studying maths at university in the pre-program survey, while 60% said they were interested in studying maths the post-program survey. Regarding students' interest in studying technology at university, the figures were also similar across both surveys, with 58% in the pre-program survey, and 55% in the post-program survey. The most notable differences in the responses was in engineering, where interest in studying engineering increased from 50% to 65%. The second most notable difference was in interest in studying arts, which rose from 58% in the pre-program survey, to 65% in the post-program survey. There was also a slight increase in interest in studying science at university, from 65% to 70%.

In terms of the students' perceptions regarding the link between STEM subjects and their future career, the percentages were very similar across the pre- and post-program surveys. Eighty-eight percent of students agreed that there were links in the pre-program survey, while this percentage increased to 90% in the post-program survey. Regarding students' perceptions on the link between arts and their future career, the percentages remained consistent at 60% across both pre- and post-program surveys.

Engineering as a profession

Students' perceived understanding of what engineers do in a professional context increased from 81% in the pre-program survey to 86% in the post-program survey. Though the students harboured some uncertainty about their aptitude for a career in engineering, over half of them (across both surveys, respectively) felt they had what it takes to become engineers. When asked about the skills or traits that engineers need to possess, three main themes emerged from the qualitative responses. The highest number of references (13 references) were made in relation to 'soft skills' and personal attributes associated with working in the field of engineering. These include the ability to problem solve, think creatively, work cooperatively, and being focused, motivated and dedicated.

Women in STEM & STEAM

All the students across both surveys agreed that women would make good engineers, and that this was a good career choice for women. The vast majority of students felt there were no barriers to women working in arts (90%), followed by science (85%), maths (60%), and finally, engineering (45%), and IT (45%). The students who said there were barriers mainly felt that they were to do with gender – e.g. being female presented an obstacle to pursuing careers in engineering because of society's perception that STEM careers are not a 'typical' female occupation.

Perceptions of parental/guardian and teacher support of studying STEM and Arts

All the students felt that their parents/guardians thought studying STEM subjects was important. Nearly all the students felt that their teachers encouraged them to study STEM (96% pre-program, 90% post-program survey). Students' views regarding the importance of arts did not differ greatly between pre (68%) and post (65%) program surveys. Similar findings were reported regarding students' perception of their teachers support in studying arts (56% pre-program, 55% post-program). The greatest difference was in students' perceptions of their parents/guardians' support of studying arts, which increased from 40% to 55%. Students' own views about the importance of studying arts was nevertheless still higher than their perception of teacher encouragement, or their perception of parental/guardian support to study arts.

Program feedback

Program feedback was predominantly positive, with an average satisfaction rating of 92% across the 10 feedback categories, based on the 20 responses received to this question from the post-program survey (see Figure 1). Students indicated that the program helped to improve their understanding of all the STEAM disciplines (see Figure 2) – science (70%), arts (70%), engineering (60%), and IT (60%). Students were however less equivocal about the program assisting their understanding of maths, with half the students indicating 'yes' and the other half indicating ‘no’. Students mentioned that their general understanding and awareness of the individual STEAM disciplines as well as how the disciplines could be combined, had improved as a result of participation in the program.

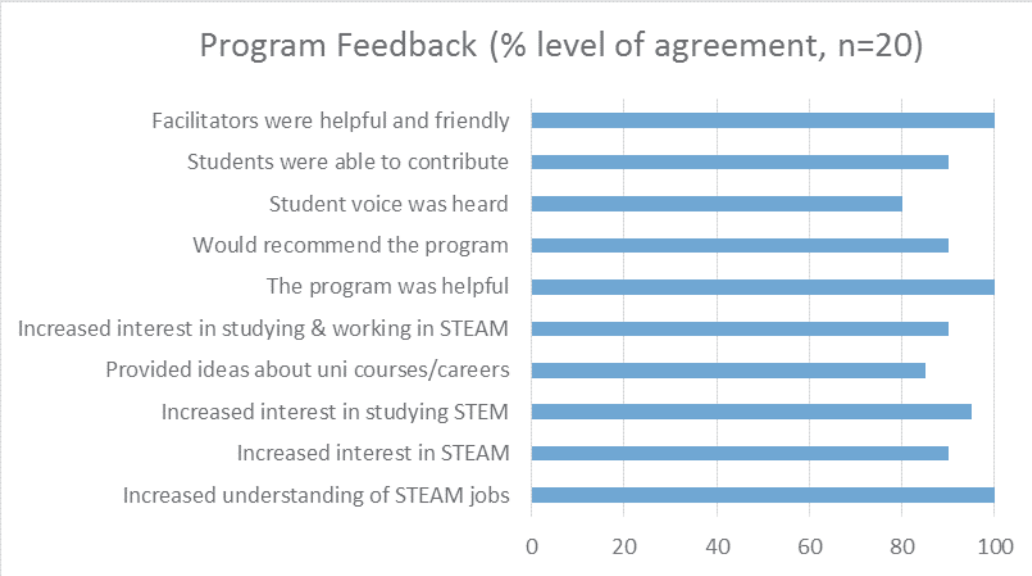

Figure 1: Program Feedback

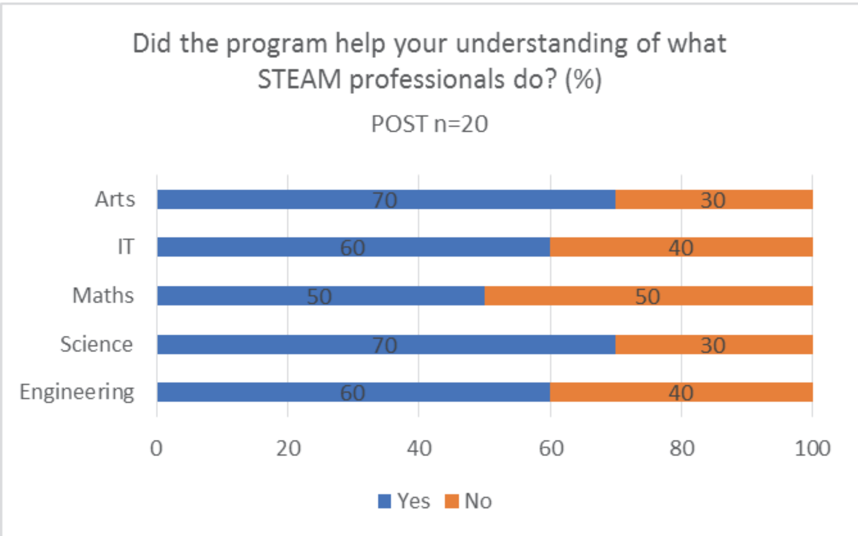

Figure 2: Students’ perception of whether their understanding of STEAM professional roles had increased as a result of the program

Discussion

The aim of the co-design program was to provide young women aged 15-16 years with an opportunity to learn more about STEAM thinking, to provide their thoughts and ideas about engagement with STEM and the arts, to meet STEAM role models, and to co-design a STEAM program for their peers. Findings from the present study revealed improvements in participants’ understanding of the all the component STEAM disciplines (except Maths), of the type of work people undertake in STEAM, and about the variety of cross-disciplinary skills and traits one needs to work in STEM industries. Related to this, participants also reported greater understanding and appreciation of how different types of knowledge can be integrated and used to address problems.

The inconclusive findings related to perceived improved understanding of maths (see Figure 2) signalled to the project team that more should be done to demonstrate the integration of quantitative-based skills and techniques (and their practitioners) into the pilot program, in a way that will be engaging and meaningful in an interdisciplinary context.

Students indicated that interest, passion and social impact were significant factors they considered in contemplating future careers. This sentiment aligns with the oft-discussed attributes of Generation Z (i.e., digitally connected, pragmatic, collaborative, entrepreneurially-minded and aspire to have their work impact on society (Hajkowicz et al., 2016)). This finding reflects past research that reports on women’s inclination to work in jobs where they feel able to be of help to others (Corbett & Hill, 2015).

Overall, the findings point to a strong preference among participants for awareness and exposure to the practical value of their learning, preferring a hands-on approach. The students wanted to see how the information and knowledge they acquire at school could be used in the community and/or in a professional context. They enjoyed learning facts, but at the same time also learning by doing. These preferences have subsequently informed the project-based learning approach utilised in the pilot program in 2017.

A more personalised, constructivist approach to learning about and applying STEAM thinking will allow students to bridge the gap between theory and practice, demonstrating utility of abstract ideas and promote engagement in STEM through exposure, practice and exemplification. Such student-centric modes of learning have been associated with increases in student self-efficacy (VanMeter-Adams et al., 2014). Integrating a social/human context to STEM may work to address issues of women’s reportedly lower perception of self-efficacy in STEM (Falk et al., 2016), even when their interest levels may already be high. In instances where women possess strong aptitudes in STEM as well as in verbal areas, the integrative and interdisciplinary nature of STEAM may appeal because it moves beyond disciplinary ‘silos’ and enables women to utilise a wider variety of aptitudes (Wang, Eccles & Kenny, 2013). It is noteworthy that the students in this study were more likely to cite soft skills ahead of (and in addition to) disciplinary or academic expertise and training required to work in engineering. This may be indicative of a higher level of awareness demonstrated by these students in relation to the array of personal and professional attributes that STEM-related professions require to operate in the modern workforce. These are the very skills which are sought after by employers and often lamented to be lacking in graduates (Sander, 2017).

All the participants perceived strong links between STEM and the kinds of jobs they might like to have in the future. They recognised the importance of studying STEM subjects, expressed high levels of confidence in STEM, and in Arts, and were confident that they could do whatever they put their mind to. They felt that women would make good engineers, but at the same time felt that there were significant barriers to women working in certain STEM roles such as engineering. This may imply that although the students may possess interest and academic aptitude, they nevertheless felt less confident about their potential professional self-efficacy in STEM fields. Aligned with this finding, Corbett and Hill (2015) refer to the unconscious gender bias (even demonstrated by women) concerning women in STEM fields. The authors found that a significant percentage of young women were pessimistic about overcoming the barriers to pursuing engineering and IT careers. The present study also found that young women were aware of societal perceptions that females possess lesser acumen or lesser aptitude for STEM fields, or have skills that are less suited to STEM. Findings regarding student, parental/guardian and teacher perceptions of the importance of studying STEM and arts subjects revealed similar opinions from these different stakeholders regarding the importance of studying STEM (i.e. near unanimous agreement that it was important), but far less congruence regarding the importance of arts. Students’ own views about the importance of studying arts was higher than their perception of their teachers’ encouragement, and their parents’/guardians’ support. This may indicate that more could be done to raise awareness among parents/guardians about the benefits and utility of integrating the arts into STEM learning. Furthermore, despite being a more STEM-inclined cohort (as indicted by their professed favourite subjects) more students expressed an interest in studying arts subjects at university *after* participating in the program. Reflecting the breadth-based model of female aptitude (Valla & Cecil, 2014), this outcome could be due to the students being more open to integrating non-STEM elements into their university programs because of a newly validated or reinforced interest and aptitude in arts. Interestingly, fewer students indicated that they wished to work in engineering or IT, despite more students indicating they wanted to study engineering at university after the program. It appeared that interest in studying engineering did not automatically translate into willingness to work in engineering. Again, the explanation could be a lack of perceived potential professional self-efficacy when it comes to engineering as a career. Further research could be undertaken in this area, to obtain more nuanced findings to elucidate this discrepancy.

Overall, the findings contribute to extant explanations of women's underrepresentation in fields such as engineering as being more than just about academic attainment and aptitude, but also about awareness, access to opportunities, perceptions of self-efficacy, and societal norms. Giving young women a safe space to experiment and fail, and to work on projects and problems that are meaningful to them, could work to mitigate the decline in women's STEM engagement. As a learning and teaching methodology, STEAM education provides a promising operational framework to achieve this.

External factors are also at play, particularly students' sources of support and influence such as parents/guardians, schools, teachers, peers, role models, and the organisations and employers they may eventually work for. Greater awareness regarding the value of interdisciplinarity and diversity in STEM among these other stakeholders would contribute enormously to creating STEM classrooms and workplaces that are more welcoming for all students (including women). STEAM can be utilised as a valuable approach and in 're-branding' contemporary STEM education and workplace cultures.

Conclusion

The co-design of the STEAMpunk Girls program has been invaluable in enabling evidence-based design of the subsequent pilot program in 2017, and in adding to a growing body of knowledge about STEAM program design and outcomes. These findings may also have wider implications for STEM and STEAM education and STEAM program and resource design. For example, education developers and instructors designing programs and resources in engineering may wish to adopt a more interdisciplinary approach, emphasising the social and human contexts as they relate to the topics at hand. Though the comparison of longitudinal student survey data is useful in identifying program outcomes, the findings reported in this study are of limited generalisability due to the use of the convenience sampling method. Further, correlational analysis was not undertaken due to the small sample size. What this permitted, however, was consideration of the breadth-based model of female underrepresentation in STEM. If young girls perceive themselves as having high interest and aptitude in both STEM-based subjects and arts subjects, educators should capitalise on this symmetry with curriculum design that can harness this inclination. This is the aim of the pilot phase of the project. The pilot phase will additionally explore the intrinsic and external factors that contribute to girls' interest and engagement in both STEM study and career, and if a STEAM approach is likely to have an impact on this interest. Findings from the pilot phase are currently being analysed and will be reported in future publications.

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Researching reflection in an engineering internship program

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SESSION C1: Integration of theory and practice in the learning and teaching process. S1: Is Integrated Engineering Education Necessary?

CONTEXT At the University of Technology Sydney, engineering students undergo a 2 phase internship program consisting of a junior and a senior 6 month internship. Students are taught a framework for reflecting on their internship experiences based on an adaption of the 4 stage Kolb cycle process informed by the work of Schon and Jarvis. Previously reported analysis of students' reflective writing has established that such writing can be taught. However, further study is required to determine if the framework used is actually achieving the intended goals of students identifying their learning, widening their understanding of its application, affecting transformation of behaviour and adopting reflection into practice as a lifelong learning skill.

PURPOSE This paper seeks to answer the question: How can rigorous research be undertaken to test whether this reflective framework is achieving its intended goals and where may teaching processes need to be improved?

APPROACH The research design in this paper is based on multiple data collection methods. Grades, reflective writing submissions, interviews, questionnaire survey, and observations serve as the major sources of data.

RESULTS Grades can be related to feedback from students and their employers and plots made from which implications about the efficacy of the framework and teaching methods can be drawn. Correlation between students' reflective writing and observation can also reveal if the framework is creating “reflective-learners”. Other observation may help reveal if reflection is adopted to establish a lifelong learning skill.

CONCLUSIONS Whilst it has been established that frameworks for reflection can be taught, this may not necessarily indicate the framework used is actually achieving the intended goals. The research approach proposed in this paper may help to answer the question of how rigorous research can be undertaken to test whether the reflective framework used is achieving its intended goals and where teaching processes may need to be improved.

KEYWORDS Reflective learning, engineering internship, learning outcome evaluation

Introduction

In their book “A whole new engineer”, Goldberg and Sommerville (2014) describe the need for engineers to be equipped with six minds: analytical, design, linguistic, people, body and mindful. From a practical perspective these largely intellectual and cognitive features are highly relevant to the shaping of future engineering professional identities. Goldberg et al. (2014) also contend that transforming engineering education to reveal the happiness of engineering is critical and that engineering education is now standing at the edge of transformation. Building life-long learning skills and self-agency through mindfulness and reflection are key components in the education of young engineers. Some of these educational transformations have already been introduced in Australian engineering education. One obvious example is perhaps the adoption of reflective learning in tertiary engineering education (Kavanagh & O’Moore, 2008).

Reflective learning aims to enhance people’s insight into their practice (Dewey, 1939), which in today’s more human resource oriented terms might be considered a lifelong learning skill. Kolb (1984) explored experiential learning and proposed a 4 stage cycle for reflection. Schön (1983) discussed reflective practice as key for developing professional competence, in particular “reflection-in-action” and “reflection-on-action”. Jarvis (1992) made a distinction between non-learning, non-reflective learning and reflective learning, and examined reflection in practice based environments.

Engineering students the University of Technology Sydney undertake a substantial two-phase internship program where a framework based on an adaption of the Kolb cycle informed by the ideas of Schön and Jarvis is taught and practiced. The motivation derived from a recognition that reflective learning would be an effective approach for developing engineering competencies in the “transferable” or “professional” skills areas used extensively by engineers in the workplace. Such skills are not always easily developed through technical coursework. Past analysis of students’ reflective writing has been done to ascertain that the reflective writing framework can be taught (Figueroa, Parker & Kadi, 2014). However, it must be acknowledged that reflective writing done in an assessment based context could be “normative” in that students may be coerced into writing what they believe the assessor wants to read (Boud, 2001). Therefore, analysis of student writing may not necessarily be strong evidence that the framework used is actually achieving the intended goals, these being: identifying their learning, widening their understanding of its application, affecting transformation of behaviour and adopting reflection into practice as a lifelong learning skill. Further study is required to determine the efficacy of the framework in these respects by answering such questions as:

1) Is there evidence students understand the wider application of their experiential learning and change behaviour as a result of implementing this reflective framework?
2) Do students and their internship employers perceive improved development in skill areas that have been the basis of a reflection – are learning outcomes improved?
3) Is reflection genuinely adopted and integrated into students’ thinking forming the basis of a lifelong learning skill – is it used voluntarily or spontaneously?

This article seeks to answer the question: How can rigorous research be undertaken to test whether this reflective framework is achieving its intended goals and where may teaching processes need to be improved?

Approach of Teaching

At the University of Technology Sydney, engineering students undergo a 2 phase internship program consisting of a junior and a senior 6 month internship bookended by preparation and review subjects. This paper focuses on the first internship phase where reflection is first taught. Prior to undertaking the first internship, students do a preparation subject in which, amongst other things, they are introduced to the reflective framework.

A 4 stage process based on Kolb's learning cycle was chosen as it was considered to be a simple, intuitive, and logical process founded in strong theory. It has been adapted to suit a practice based engineering environment based on the ideas of Schön and Jarvis. In particular, the framework focuses the "Abstraction" and "Experimentation" stages as being a way to translate what has been learned in a specific situation into a wider context so as to recognise its broad application and then to plan for future improvement.

During their first internship, students are required to maintain a reflective learning journal in which they must write, as a minimum, one reflection every 4 weeks. In Weeks 4, 12 and 20, students are free to reflect on an experience they have had recently at work where they encountered and learnt about a transferable or professional engineering skill used in the workplace. Some topic prompting is provided including communication, time management, stress management, assertiveness, problem solving, teamwork, and others. In Week 8, students are required to reflect on one aspect of their performance they have learnt about through a Performance Review they are required to arrange with their workplace supervisor in the preceding week. In Week 16, students are required to reflect on how successful their plan was to improve in the skill area reflected on in Week 8 – i.e. what did they learn about their approach to learning and how might they improve.

Boud (2001) argues that it is not appropriate to grade reflective writing based on whether or not the experience being reflected on and the learning derived from it is "important" or "good". However, assessment and feedback in this phase of the internship program is largely based on how fully and consistently the student has applied the framework taught as opposed to the "quality" of the experience being reflected on or the writing itself.

Assessment is done via a rubric and tutors are trained about the framework and how to assess its application in students' reflective writing. A set of standardised feedback comments is circulated to tutors. Whilst tutors can make their own comments if required, they are encouraged to use the standard comments (or combinations and adaptions of them) whenever possible to ensure consistency. The rubric and feedback comments are designed to focus on the structure of the reflection and how completely the student has addressed the guideline questions and criteria in the framework. The rubric comprises 5 columns going from Very Poor (0%), Poor (25%), Adequate (50%), Good (75%), to Excellent (100%). The framework and assessment rubric are discussed below.

In stage 1 of the framework, students are asked to document a recent workplace experience, their role in it, what they expected would happen going in to the experience and what the actual outcome was. This is assessed as a single row in the rubric worth 13% based on how clearly they describe the experience, their expectations and the actual outcome.

Stage 2 of the framework is covered in two parts. Firstly, students should analyse why this outcome occurred. They are asked to consider what actions of theirs and what actions of those around them might have contributed to the outcome. They should discuss the emotions and feelings they were experiencing at the time of the experience and also when considering it in hindsight. This is intended to create awareness in students that their emotional reactions during an experience influence how they handle it and their emotions when remembering it later may influence how they approach this type of situation in future. If appropriate, there should be discussion of any external, or non-human, factors that may have contributed to the outcome (such as hardware or software issues, weather events, procedural requirements, etc). Finally, they should evaluate their performance given the circumstances at play. This is assessed as one row of the rubric worth 13% based on how thoroughly these prompts have been discussed. The second part of Stage 2 requires the student to focus on one main thing they have learnt from this experience and articulate this concisely as a skill relevant to professional engineering practice - establishing a skill area "theme" for the reflection. This is assessed as one row in the rubric worth 13% based on whether they can focus on one key "lesson" and how relevant this is to engineering practice.

Stage 3 of the framework is covered in two parts. Firstly, students are asked to abstract their "lesson" by describing two engineering related situations in which they think it could be applied that are different to each other and to the original experience. This is designed to help them recognise that learning obtained in a specific situation has wider application. This is assessed as one row in the rubric worth 17.5% based on whether the examples are consistent with the "lesson" from Stage 2, the relevance of the examples to professional engineering, if they have at least two examples and how different and wide ranging the examples are (the degree of abstraction). The second part requires students to do some research (get external input) into a tool or method to improve performance in this skill area. It is considered that once they recognise the broader implications and application of their "lesson" they are well placed to find a method or tool that can be applied widely. This is assessed as one row in the rubric worth 17.5% based on whether or not a tool or method is identified and whether there is evidence this has been found through research (i.e. it is new to the student and a citation is provided) or if it is something they thought of themselves or already knew.

Stage 4 of the framework is covered in two parts. Firstly, students are required to discuss their plan for future improvement based on how they will implement the tool or method they have found from research. This is assessed as one row in the rubric worth 13% based on how clearly the plan is articulated, if it consistent with the skill area "theme" originally identified and if it is based on research findings. Secondly, students are required to discuss what evidence they have that the plan is likely to work, to discuss why they think it is a plan they are likely to want to use in future and why it is a plan that suits the situations in which they expect to work. This is assessed as one row in the rubric worth 13% based on how fully these points are discussed.

Extra weighting is placed on the Stage 3 "Abstraction" part as this is considered to be the key that enables "reflection-on-action" or true "reflective learning" to occur, leading to understanding of the wider application of learning and the subsequent generalised transformation of behaviour. To borrow form Gray, Cundell, Hay & O'Neill (2004), only when experience or route learning are "integrated with practice, evaluation and/or reasoning and reflection does it lead to reflective learning that includes the ability to apply skills and knowledge to unique or novel situations".

Hypothesis

Referring to Jarvis (1992), the distinction between non–learners and learners draws upon the ability of learners to avoid repeating the same mistakes. Further, reflective learners differ from non-reflective learners in their ability to recognise the wider application of this learning, consider ways to improve and then manifest this generally in their practice. Schön (1983) discusses "reflection-on-action" as being a process of analysing the causes of an unexpected outcome to help recognise what needs to be changed in order to improve future performance. Gray et al. (2004) also contend that reflective learning leads to the application of acquired knowledge into solving new problems. In this respect, students who have been taught the reflective framework outlined in this paper can be differentiated into non-learners, non-reflective learners and reflective learners.

With the definitions above, compliance to the reflective framework, perceptions of benefits and evidence of application of learning into a new contexts serve as the indicators of measurements toward a relatively more comprehensive evaluation of effectiveness concerning the teaching and learning of the framework. Students may also be differentiated into adopters and non-adopters if evidence of voluntary or spontaneous application of the framework can be found.

Because of the way assessment is conducted, marks can be used as an indicator of how fully and correctly the framework has been applied and also contributes to understanding the effectiveness of the teaching and feedback approach.

Students' feedback or their self-evaluation of the learning experience reflected in this proposed research derives from their perceptions of benefits – in terms of competency development – gained from exercising the reflective framework. Similarly, employer evaluation of the effectiveness of the framework derives from their perceptions of students' improvement which can be correlated against skill areas that students reflected on. In this way, feedback can be mapped against marks with individual students represented in a node differentiated by a particular shape, as follows:

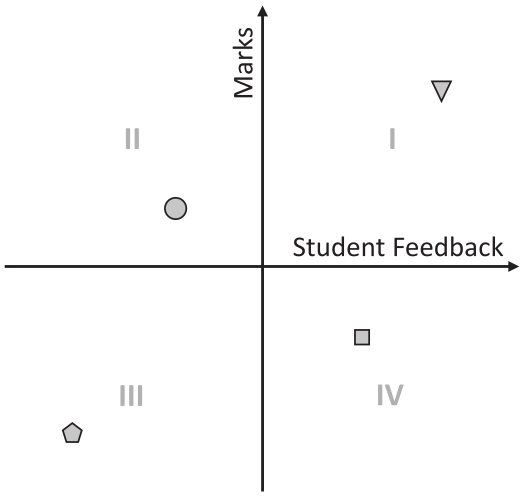

Figure 1: Student Data

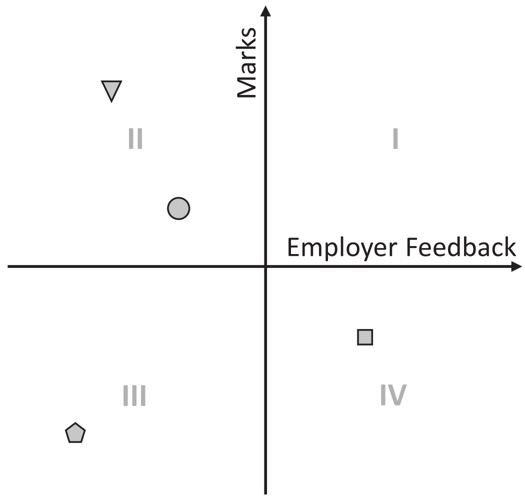

Figure 2: Employer Data

Figure 1 shows possible illustrations of student performance of reflective learning. Each quadrant indicates a scenario of performance. In this diagram, Quadrant I, indicates positive recognition of benefits together with high conformance with the reflective thinking framework. Quadrant II depicts negative recognition of benefits but conformance with teaching requirements. Quadrant III shows both negative results. Quadrant IV reveals positive recognition but negative conformance.

Figure 2 shows the student's performance from the employer perspective. The horizontal axis is replaced by employer feedback toward the benefits of reflective learning. It is noticed that employer may not have the same recognition of benefits as the student. Therefore, nodes may move horizontally as illustrated by the triangular node in the above diagrams.

The hypothesis is that a high density of student or employer feedback nodes located in quadrant I coupled with observation of learning applied in novel situations is an indicator that the framework is producing reflective-learners. Higher correlation between student and employer feedback increases confidence in the data.

A corollary is that observation of students encountering new skills and later applying these in novel situations during times they are not required to undertake reflections as part of assessment activities, may imply that adoption of the framework has occurred inferring acquisition of a lifelong learning ability.

Data Collection Methods

Data collection for this research consists of two parts: firstly, a collection of feedback from both students and their employers and secondly, observation of students following internships.

The first part of empirical data can be collected from questionnaire surveys and/or open ended one-to-one interviews – to ensure independent response. Similar surveys and/or interviews with different questions can be done with their internship employers.

Observation can be carried out during student group projects done in subjects undertaken after their internship. Provided a student demonstrates an ability to problematize new situations and expresses a solution developed through a past reflective thinking process, his or her benefit from the reflective learning framework can be positively identified. Supported by student's learning journals in the first internship, abstraction of learning into novel situations can thus be traced.

The adoption of observation as a research methodology in this study can also be supported by some empirical evidence such as students' self-evaluation of their skills development mentioned in their reports submitted in the review subject undertaken following their internship. Although, it is not mandatory for students to claim for their progress using the framework taught, substantial evidence exists to show they demonstrate such progression with claims of adopting learning gained during their internship.

Expected Results and Discussion

The analysis of plotting student and employer feedback against marks should allow a number of conclusions to be drawn regarding how effectively the framework is being taught and whether the framework improves skills development. The distribution or density of results across the quadrants will be of particular interest. Some possible implications from this analysis might be as described in the tables below:

Table1: Feedback Plot Interpretation

Quadrant	Meaning	Implications
I	Framework has been applied reasonably correctly Reflection is perceived to be useful	Framework application is taught effectively. Framework appears to benefit learning outcomes. Student is reporting what they think is expected of them (rather than real opinion).
II	Framework has been applied reasonably correctly Reflection is not perceived to be useful	Framework application is taught effectively. Framework appears to require change (is not benefitting learning outcomes). Student does not value learning that the framework facilitates. Employer is not satisfied with skill advancement demonstrated by student to-date.
III	Framework has not been applied correctly Reflection is not perceived to be useful	Student is disengaged from process (communication and teaching around reflection and the framework need improving). Student does not value learning that the framework facilitates. Employer is not satisfied with skill advancement demonstrated by student to-date.

IV	Framework has not been applied correctly Reflection is perceived to be useful	Reflection is beneficial even if not done in accordance with the framework. Teaching of framework application needs improving. Student is reporting what they think is expected of them (rather than real opinion).

Additionally, analysis of any divergence between employer data and student data, both individual and collective, can also be examined. Divergence will only occur in the horizontal plane as the mark for a student will not change between student and employer plots.

Provided general agreement exists between the student perception and the employer perception (i.e. the data nodes are in the same quadrant) then there can be high confidence in that node. However, two possible divergences can occur, as outlined in the following table:

Table 2: Student/Employer Plot Comparison

Quadrant	Implication
Student II or III Employer I or IV	Student does not value the “soft” skills that the reflective framework facilitates. Employer does value “soft” skills. Student does not recognise their level of progress. Student considers reflective writing is not engineering relevant.
Student I or IV Employer II or III	Student is reporting what they think is expected of them (rather than real opinion). Employer has not had sufficient time to evaluate student progress. Employer feels student has not progressed skill to a high enough level even if student sees progress in themselves. Student and employer have different perception of what various skills mean.

Observation of a student in post-internship group work situations in university subjects can be correlated with reflections they have written whilst on internship. Skill areas they have reflected on can be identified and their behaviour observed to see if there is evidence that the learning described in reflections is abstracted and its application to new contexts is recognised, with the plan prepared during reflection applied into the new context.

Further, observation of students could also reveal if new learning encountered in these group work situations is subsequently applied by students into other future new situations. If this can be detected, it may infer that the reflection framework is being applied by students voluntarily or spontaneously, which would indicate the goal of establishing a lifelong learning technique through reflection may have been achieved.

Conclusions

Whilst it has been established that frameworks for reflection can be taught, this may not necessarily indicate the framework used is actually achieving the intended goals. The research approach proposed in this paper may help to answer the question of how rigorous research can be undertaken to test whether the reflective framework used is achieving its intended goals and where teaching processes may need to be improved.

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Teaching Advanced Computing Technologies to Managers, Engineers and Other Professionals

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CONTEXT Nowadays most businesses in Australia maintain a website to advertise their products and services and some to also conduct online sales and payments. Many have an additional Facebook page or utilise other on-line tools and phone apps. Data is now considered to be one of the most valuable assets of companies, and many are using Cloud services for safe storage and data processing. With the rapid growth of the volume and diversity of collected data, and its increasing importance for strategic planning, many businesses have started using big data analytics techniques to extract knowledge from data to support their decisions. All of the above technologies require formal security management or otherwise they can become a weak link which can create security vulnerabilities and expose company assets. While some of the computing tasks and their associated security can be outsourced to specialised IT companies, it is crucial that business managers and professionals have sufficient conceptual understanding of these topics in order to make quality decisions and ensure the survival of their business in the modern world.

PURPOSE The question studied it this paper is how best to teach advanced computing technologies to business managers, engineers and other professionals with different prior experience and educational backgrounds.

APPROACH We describe a curriculum for teaching the most relevant computing technologies to professionals working in various branches of industry and business, mostly based on a Graduate Certificate in Advanced Computing Technologies for Business, currently being taught in an intensive weekend mode. A similar program could also be taught online with one intensive face-to-face session per course.

RESULTS The limited analysis possible during the first run of the program indicates that the delivered courses were well-received by the students who have been able to successfully master the curriculum presented in an intensive weekend delivery mode.

CONCLUSIONS While virtually all Australian universities have programs for training IT professionals, apart for a few isolated courses, few universities provide opportunities for other graduates to learn the most relevant computing technologies. Such programs should be developed and included in engineering and business coursework Masters programs and made available to middle and senior business managers.

KEYWORDS Cloud Computing, Big Data, IT Security.

Introduction

Nowadays virtually all businesses in Australia and the Western world maintain an online presence. Some use it only to announce their contact details and opening hours, others to advertise their product and services, while a growing number use their websites for e-commerce, including on-line payment systems. While having an online presence offers businesses exposure to customers that they would have otherwise not be able to reach and convenience of electronic commerce, companies' Web servers also represent a gateway for hackers and malware that could potentially infect and compromise the computer system of the company (Stallings, 2017). This year alone we have witnessed an alarming number of businesses falling victim to ransomware, such as WannaCry (Symantec Security Response 2017), malicious software that encrypts all data files on the server and where the decryption key is made available only after a ransom has been paid to the attackers. The yearly cost of ransomware in Australia has been conservatively estimated to a billion Australian dollars (Belot & Borys, 2017) while the global cost of cybercrime has been expected to reach six trillion US dollars in 2021 (Morgan, 2016).

Not surprisingly, there is shortage of cybersecurity personnel, with around one million new cybersecurity jobs in 2016 (Morgan, 2016). Possibly more importantly, businesses are still reluctant to invest into cybersecurity, thus bearing unnecessarily high cost of data breaches, averaging 1.3 million US dollars for enterprises and 117,000 US dollars for small business per incident in North America in 2017 (Kaspersky Lab, 2017). In this context, the role of universities in Australia and worldwide is not only to establish degrees to graduate a sufficient number of cybersecurity specialists but also to provide cybersecurity courses and programs suitable for business managers, engineers, IT and other professional, so as to raise awareness of importance of cybersecurity and facilitate better informed decision making.

The situation is similar in other areas where technology meets business. For example, for many years Data Mining has been a subject that involved a solid education in machine learning, applied statistics and relevant database techniques. Recently the field experienced a massive boom due to the availability of an abundance of data on the internet, the success of Google's search engines, the availability of GPU computing and the so called "Big Bang of Artificial Intelligence". The latter occurred in about 2012 when it was suddenly recognised that artificial neural networks, after some design changes that added several hidden layers of neurons, can solve many challenging pattern recognition and control tasks that the community and relevant industries have been struggling with for the past twenty years (Krizhevsky et al., 2012). This new paradigm, called "Deep Learning", made headlines on all machine learning blogs for the past five years (Goodfellow et al., 2016). The majority of papers at all major machine learning conferences currently involve deep learning.

Major companies such as Facebook and Google have already made substantial investments into deep learning (for example, Google acquired DeepMind Technologies in 2014) and other companies now massively investing in this field including social media, finance and the transforming automotive industry, hoping to tap into possibilities presented by deep learning. There is a high demand for competent graduates in data analytics from industry. Student numbers in classes on AI and machine learning have increased by factors of 2-4 at many Australian Universities. However, what currently is missing are courses and programs suitable for managers and other professionals.

Cloud Computing is another area experiencing high growth. Managers are increasingly becoming required to understand concepts of scalability and resource management so they can direct IT resources within their organisations. There is a lack of courseware currently available that is able to teach highly technical concepts such as how the Cloud works to non-technical audiences.

In this paper, we explore opportunities for cross-disciplinary courses and programs teaching advanced computing technologies to business managers, engineers, IT and other professionals. We present a curriculum mostly based on the Graduate Certificate in Advanced Computing Technologies for Business that is currently running in an intensive weekend mode to accommodate students who are working full time.

Curriculum

The following curriculum combines modules in the acutely important domains of IT security, Cloud Computing and Big Data Analytics. The aim of the program is to provide managers and professionals with the necessary conceptual knowledge to lead teams of data scientists, security and privacy experts and storage specialists, and to be able to make informed decisions. None of the modules requires specific prerequisites and all the modules have the aim to educate students about the most important concepts and tools in the domain. The delivery mode can be either face-to-face intensive mode, preferably on weekends to accommodate full-time working students, or online mode with occasional face-to-face sessions.

The assessment is similar for all modules and includes online quizzes, a research report and a presentation. The purpose of the online quizzes is to examine the knowledge and deeper understanding acquired in the module, as well as the students' ability to continue independent learning. The quizzes consist of a combination of multiple-choice questions, short answers and mini projects. For the research report, the students independently explore a given topic and describe their findings in a report, and present it orally in the class. Such assessment is more suitable for the cross-disciplinary student cohort and takes them away from the rigidity of the classical exam.

We next outline the various modules as presented in the graduate certificate program.

Privacy

Table 1: Privacy topics

What is privacy? • Definition • Examples of privacy breaches
Privacy history • Did people enjoy privacy throughout history or is it a modern invention?
Psychological aspects • Do we, as individuals, need privacy for our mental wellbeing?
Privacy and human rights • Privacy International
Privacy laws, regulations and acts in different countries • Australia (Privacy Act and its amendments; Australian Privacy Principles) • USA • European Union
Security vs privacy • Understanding the relationship between security and privacy
Data collection, publishing and mining, and associated privacy issues • Privacy preserving data publishing (k-anonymity, differential privacy, etc.) • Balance between privacy and utility
Privacy-enhancing technologies and tools • Virtual Private Networks • Communication anonymisers, private browsing and search engines • Encrypt your emails - PGP • Private Messaging

Understanding privacy principles and privacy obligations towards clients is very important for those business and government sectors that collect and manage any kind of personal data. The students are taught their legal obligations in terms of handling such data. The students are also invited to explore privacy as individuals, from a socio-psychological perspective, to be able to fully understand the point of view of organisational clients. In Table 1, the privacy topics are grouped into socio-psychological, legal and technological aspects and coded as yellow, red and blue, respectively, while their overlaps are presented in orange and purple.

Computer Crime

In the computer crime module, the students gain systematic knowledge of types and techniques using in computer crime, as well as the most important counter-measures.

Table 2: Computer crime topics

What is computer crime? • Definition • Examples of computer crime
Types of Cybercrime • Computers as targets • Computers as storage devices • Computers as communications tools
Cybercrime Techniques • Hacking (unauthorized access) - Computer Emergency Response Teams (CERTs). • Malware (Types of malware: viruses, worms, Trojan horses, logic bombs, trapdoors, zombies (bots), etc.; antivirus software) • Distributed Denial of Service Attack (DDoS) and DDoS Countermeasures • Spam • Phishing • Social Engineering
Cybercrime classification • Fraud, Online Scams and Other Theft • Illegal/unauthorized Advertising • Extortion/Threat • Espionage and Cyberwarfare
Cybercrime and the Internet of Things • Examples
Cost of Computer Crime
Intellectual Property (IP) • Copyrights; trademarks; patents

Computer Ethics

Table 3: Computer ethics topics

What is ethics? • Definition; examples
Ethical theories • Metaethics • Nominative Ethics   o Utilitarianism; Deontology; Virtue Ethics • Applied Ethics
Computer Ethics • What are the specifics of computer ethics
Examples
Code of Conduct • ACM, IEEE and AITP codes; Google, Lego, Uber

On successful completion of this module, students are able to understand basic ethical concepts and theories, and design principles of conduct that can guide ethical decision making in various contexts. Students first learn the basic ethical theories and then learn about specific contexts created by the proliferation of computer and networking technologies.

Computer Security

This module prepares students to understand a variety of IT security attacks, mechanisms and services, apply fundamental technical skills to assess security threats, vulnerabilities and risks, and apply the necessary skills for bridging the gap between managers and technical personnel to enable efficient communication and decision making. The students were taught the basic principles of cryptography, network security, malware, intrusion and firewalls. After each topic we conducted a hands-on workshop where they broke ciphers, and with our industry partners they performed some basic ethical hacking and studied a piece of malware specially created for the use in the class.

Table 4: Computer security topics

Security attacks, services and mechanisms
Classical ciphers
Breaking classical ciphers hands-on
Breaking classical ciphers hand-on workshop
Modern Cryptography • Stream and block ciphers • Public key cryptography • MAC and hash function • Digital signature
Network Security • Message authentication • Evolution of Networks and Network Security • TCP/IP Security • Wireless Network Security
Ethical Hacking hands-on workshop
Malware • Intruders • Firewalls • Usable Security • Malware
Malware hands-on workshop

Security Risk Management

On successful completion of this module, students are able to understand the theory of and different approaches to risk management, and communicate risk to IT professionals and senior managers to facilitate decision-making.

Table 5: Security risk management topics

What is Risk?
Exposure to Risk
Risk Management Standards
Risk Management Process
Risk Assessment
Risk Reporting

Cloud Computing

In this module the students learn the basics of cloud computing and how it can benefit an organisation in terms of computing power, storage and applications.

Table 6: Cloud computing topics

A review of classic storage systems
What is the Cloud?
How business can leverage the Cloud for storage.
A review of Open and Commercial Cloud offerings
Greenfields vs Migration to the Cloud
Hands-on computer experiments in guided lab workshops

We specifically ask students in this module to apply their domain knowledge and how Cloud Computing can be used in areas they are familiar with. There is a focus on both introducing the technologies used within the Cloud as well as use-cases of common Cloud deployments.

The students were given the task of providing a cost/benefit analysis of a particular common issue with Cloud Computing where they had the opportunity to research and expand upon the course learnings further.

Big Data Analytics

The Big Data Analytics module teaches students the most important concepts and tools that are required to understand the opportunities and challenges that Big Data Analytics faces in the current development of the field and in close connection to relevant aspects of privacy, security and storage technologies.

The offerings of the module in 2016 and 2017 had several students from engineering management degrees but also IT professionals. While most students were sufficiently technically competent and open to receive the technical aspects of the course they were specifically interested in topics that were socially and ethically critical. For example, big data analytics provides enormous new opportunities and power to companies such as Facebook, Google, Netflix and Amazon where the full extent of impact and future consequences for the global society are still unknown.

With the increasing power and abilities of data analytics tools comes also a higher risk with respect to privacy and security and increasing challenges for networking and storage. This module combined topics in all three domains.

Table 6: Big data analytics topics

Introduction to Machine Learning and Data Mining
Introduction to Deep Learning
Big Data case studies; Storing Big Data and Security Issues
Big Data case studies; Hands-on Work in Python and Machine Learning Applications

Data analytics algorithms, their evaluation and the correct interpretation of results can involve advanced mathematical concepts. A challenge in course delivery was the diverse, and for some course participants non-existent, mathematical background in basic statistics, calculus and vector geometry. Therefore, a mode of Tailored Blended Learning (TBL) was applied where each student could be individually mentored during the intense face-to-face sessions on the weekends and via on-line communication while working on assignments during the week.

Due to TBL a satisfying program of topics at AQF level 8 could be selected for each individual student and her/his course project.

Among the concepts and topics to be addressed were some of the basic and fundamental concepts of machine learning such as supervised classification, generalisation, cross-validation, hyperplane geometry, perceptrons, evolutionary algorithms, support vector machines. Further required was knowledge of potential issues that can cause errors such as overfitting and the curse of dimensionality. This was paired with teaching techniques and concepts for classifier evaluation and quality assessment of outcomes such as precision and recall and receiver operating characteristics.

With respect to practical tutorials the course included a brief introduction to Python, Scikit-Learn, Tensorflow and Keras (Géron, 2017). These were taught and practiced using Jupyter notebooks. For accelerating the Deep Learning exercises and allowing a TBL approach for larger classes we plan to employ the UON GPU facilities in future offerings.

Next to a general understanding of data analytics technologies, associated potential pitfalls and quality assurance techniques a practical experience with deep learning (Goodfellow et al., 2016) was a major learning goal of the course. Knowledge of the disruptive impact that deep learning currently has on businesses that use Big Data Analytics is particularly important for start-ups in this domain.

Discussion

From an educational perspective, there is a challenge for Australian Universities to adjust quickly enough to provide all the graduates that industry requires to stay up-to-date with the extremely fast pace of technological development in big data analytics, storage and security. For relevant industries in this sector these technologies are critical to survive and take advantage of the associated industrial transformations, for example, in the automotive sector, medical imaging and many other application domains of big data analytics.

A student who previously was educated to become a “Data Miner” will now be called a “Data Scientist”. The name change could be regarded as an upgrade that reflects the changes of a field that has grown rapidly and now involves advanced techniques not only from applied statistics and traditional data mining, but also statistical physics, topology, differential geometry, logic, neuroscience and various other scientific domains. However, in practice, the name upgrade could also be seen as an attempt to cover-up or counter-balance the many challenges that education in this area faces. The pressure of fast education in this area has to combat the traditionally slow adjustment of educational institutions and the difficulty to acquire appropriate computing equipment and course materials fast enough.

While most Australian universities have programs for training IT professionals, several universities have specialised cybersecurity undergraduate programs, including Edith Cowan University, Deakin University, and University of South Australia. Some universities offer multidisciplinary degrees such as Bachelor of Cyber Security and Behaviour at Western Sydney University or Master of Cybersecurity (Law, Business Ops & IT) at Latrobe University.

However, apart for a few isolated courses, few universities provide opportunities for other graduates to learn the most relevant computing technologies. Such programs should be developed and included in engineering and business coursework Masters Programs and made available to middle and senior business managers.

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An Integrating Teaching Resource for Materials Science and Engineering

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CONTEXT The academic areas of Materials Science and Materials Engineering have different emphasis at different universities. Some would argue that the former is more focused on understanding materials (the *why*) while the latter is more focused on making use of them (the *how*). Together, they constitute an important part of many engineering programs and may therefore be treated jointly as Materials Science and Engineering (MS&E). Teaching resources that integrate these perspectives, spanning the microscopic aspects (structure) of materials and the macroscopic aspects (properties) would be very useful to educators.

PURPOSE In this paper, we describe the development and implementation of a new prototype database with tools for the teaching of MS&E, based on a standard software package for materials-related teaching, with the intention of getting feedback on our ideas.

APPROACH We have investigated a number of curricula and syllabi to identify a list of topics/concepts that appear central to the learning objectives of MS&E and surveyed/interviewed educators teaching MS&E to understand their priorities on the introductory course. Some relevant existing online resources were also reviewed with the aim to strengthen these areas with a more visual and engaging teaching tool. The results from this analysis constituted the basis for the development of a new prototype MS&E software tool.

RESULTS Among the top candidate areas that came out of the syllabus analysis and surveys were: *Microstructure processing (thermal/mechanical)*, *Material characterization and micrographs*, *Binary phase diagrams*, *Crystal structures*, and *Material properties*. The resulting prototype cover several of these topics and is part of a long-term effort to facilitate materials teaching. It integrates a multitude of teaching approaches and is currently being evaluated by professors.

CONCLUSIONS In this paper, we report on the background, development, and content of a new ambitious MS&E software tool for engineering education. The purpose is not to investigate the teaching outcome (yet), but to share our efforts and findings with educators in the field hoping to get feed-back and inspire educational ideas.

KEYWORDS Materials, Software, Teaching.

Introduction

Material Science and Engineering (MS&E) teaching forms part of a number of engineering programs relating to materials teaching, *e.g.*, mechanical (see Figure 1, coloured circles).

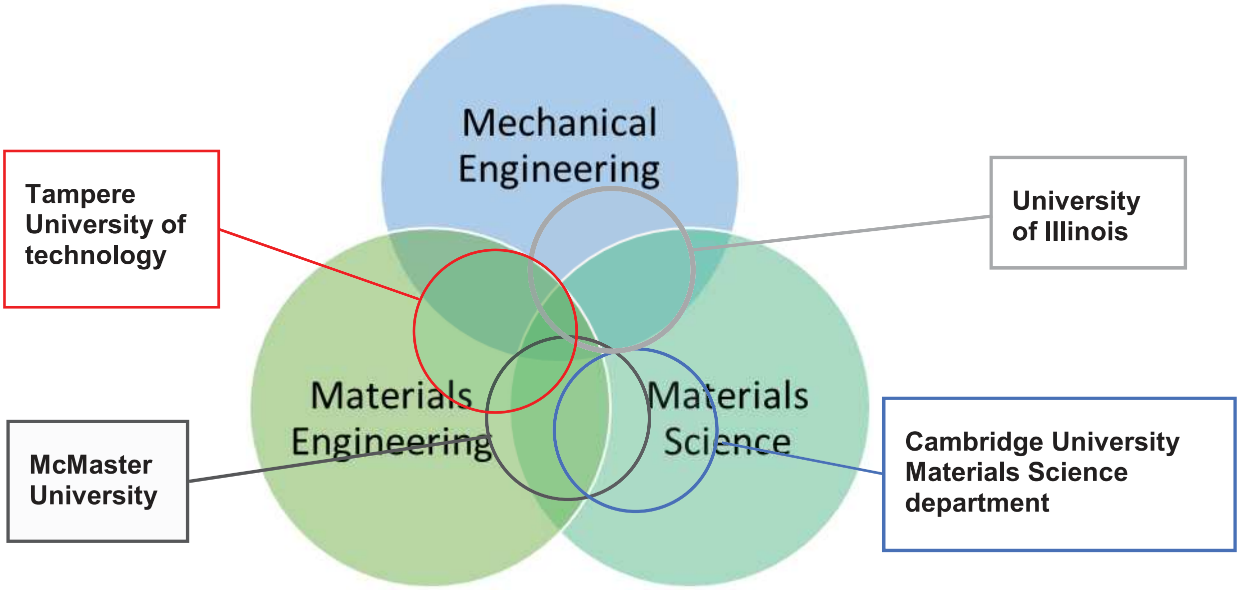

Figure 1: Venn-diagram of educational disciplines showing the emphasis placed on the subsets in the MS&E Curricula/Syllabi at four of the Universities included in this study

Traditional Materials Science courses tend to be *Science-driven*, focussing on the atomic and microscopic scales to develop an understanding of material behaviour. Materials courses in engineering tend instead to be *Design-driven* (see Figure 2), with more focus on applications and selection (Ashby, 2016). This paper considers the further development of an existing software teaching resource, CES EduPack (Granta Design, 2017), to provide a tool that can support integrated teaching with either or both of these approaches.

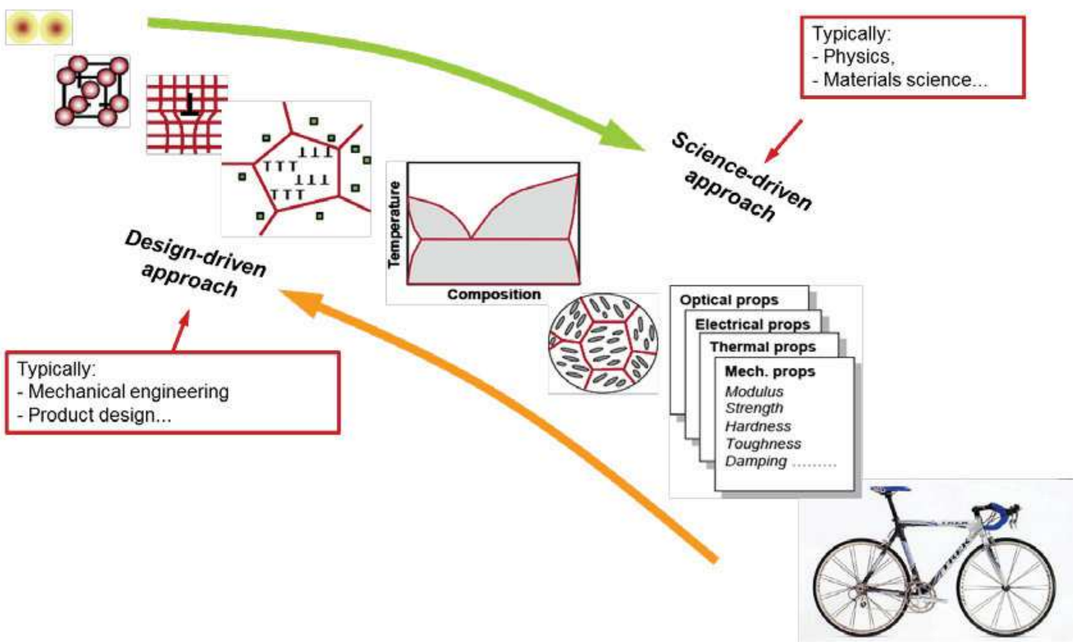

Figure 2: Design-driven and a Science-driven teaching approaches to the teaching of Materials

Background and Methodology

Syllabus Comparison

Globally, University Curricula of Materials Science and Engineering vary considerably. Six relevant syllabi (see Table 1) were studied to identify target areas and key learning outcomes. The selection was designed to reflect both geographical differences and the differences in approach depicted in Figure 2. Figure 1 indicates how they compare.

Table 1: Description of the courses selected to represent relevant syllabi

#	University	Degree	Course Syllabus
1	Tampere University of Technology (Finland)	MSci	Materials Engineering
2	Cambridge University (UK), Material Science	MSci	Materials Science
3	University of Illinois (US)	BSc	Materials Science and Engineering
4	McMaster University (Canada)	BSc	Materials Engineering
5	University of New South Wales (Australia)	BE	Materials Science and Engineering
6	Kyushu University (Japan)	MSci	International Materials Science and Engineering

Outcome of Curriculum/Syllabus Analysis

The learning outcomes, or in some cases the corresponding content of the syllabus, were compared and analysed for the six courses mentioned above. These are summarized in Table 2, below.

Some concepts that appear important to the desired learning outcomes (see marking in Table 2) were extracted and summarized below. These areas become main candidates for components of a MS&E resource:

- Microstructure processing (heat treatments etc.)
- Material characterization and micrographs
- Phase diagrams
- Crystal structures
- Material properties

In this paper, we have extended a previous study (Fredriksson, 2015), where the methodology is described in greater detail. In that study, a small survey (n=10) of professors that were experienced users of the software platform was conducted to probe the relevance of main concept areas similar to these key learning outcomes. A number of informal interviews have also been conducted to clarify the findings.The results of the survey, shown in Table 3 further down, was therefore also used to guide the development described in this work. It represents software development that is a first major step towards an integrated tool for integrated teaching of the materials science and engineering subject. Depending on feedback, further development will be guided by these outcomes.

Table 2. Learning outcomes from selected syllabi (from web) projected onto discipline: 1 Tampere University of Technology (Finland), 2 Cambridge University (UK), Materials Science Dep, 3 University of Illinois (US), 4 McMaster University (Canada) 5 University of New South Wales (Australia), 6 Kyushu University (Japan). Key concepts are marked in bold font.

#	Learning outcomes/content relating to Materials Engineering	…relating to Materials Science	…relating to Mechanical Engineering
1	• Broad knowledge of the **material properties**, their utilization, and **development of these properties** to meet the requirements set by different applications. • Broad knowledge on the development, properties and **behaviour of metallic and ceramic materials under various conditions** and in different applications. • Understanding of **manufacturing technologies** and how they are used to affect properties and structure	• Understand basic **structure-property relationships**. • Understand research **techniques and methods**. • Knowledge with emphasis on **structure/properties** of polymers and biomaterials	• Understanding **how to utilize properties** in practice, apply knowledge in **materials selection**
2	• Some attention to processing and what are the results of that. Often analysed through **microstructural behaviour** as well	• Property relations to **microstructure, material analysis methods, microstructure processing.** • Understanding the cause of the properties/results. • Investigating **material behaviour**	• Very brief introduction to **material selection** and merit indices
3	• Materials Synthesis and processing cover the **methods to alter the microstructure**	• Understanding of materials via **microstructure, predicting properties** and looking at their causes. • **Techniques of microstructural analysis** • Atomic bonds	• Many courses eventually lead to the application of **material properties** in design. • Courses on pure mechanics
4	• Minerals and **materials preparation, extraction, manufacturing, processing**. • Polymer synthesis, **metallurgy**. • Selection of processes for industrial applications (with much attention to Iron and **Steel making processes and their selection**). • Application of materials in electronics and fabrication techniques for electronics. • **Corrosion protection**.	• Nature of **defects in microstructure**, functional properties, **crystal structure**, bonding. • Thermodynamics in materials, **Phase diagrams** • **Crystal structure** properties and analysis. • Being able to mathematically model diffusion processes, **creep, corrosion** (separate course on corrosion and sustainability). • **Microstructure and mechanical property relations** (especially for **failure**)	• **Materials selection** based on materials properties. • Laws of **thermodynamics**
5	• **Microstructure control** and its application to commercial materials. • **Sustainable materials processing** (design of sustainable systems). • Common methods of metal forming. • Behaviour of common aluminium and nickel alloys to illustrate **microstructural principles**. • **Ceramic processing methods**. • Heat and mass transfer in **metallurgy**	• Microstructure and structure-property relationships. Crystallography Micromechanisms of **deformations, fracture, fatigue, creep**. • Functional properties of materials. • **Materials characterization**, • Diffusion and kinetics. • **Phase transformations** (see web). • Polymer science ranges from chemistry to full scale commercial manufacturing.	• Deformation and yielding, **failure, mechanical behaviour of materials** (with references to microstructure where applicable). • Pure thermofluid dynamics and heat transfer.
6	• Innovations and rapid advancements in materials to achieve ultimate performance • **Develop new advanced materials** • **Processes** for developing advanced materials	• Understanding the **structures and properties** of various materials • **Knowledge about metals, alloys, ceramics, semiconductors, and composites**	• Mechanical properties of advanced structural materials • Casting and Weld **Process Technology** • Smelting and **resource recycling** • Solving **environmental problems**.

Survey of Current Resources Available

We have reviewed the content of some online resources for MS&E teaching. These included:

DoITPoMS, *Dissemination of IT for the Promotion of Materials Science***,** a freely available teaching resource created by the Materials Science Department of Cambridge University (2017). It offers teaching and learning packages, lecture demonstrations, a library of micrographs and short videos.

ASM International offers an extensive library of Micrographs, Phase diagrams, Crystallographic structures and Failure Case Studies (ASM International, 2017).

F*A*C*T, the Facility for the Analysis of Chemical Thermodynamics, created by Ecole Polytechnique and McGill University in Montreal (Bélisle, 2015), provides thermodynamic data for engineering alloys and compounds.

MATTER is a resource for Materials Science created by the University of Liverpool (MATTER, 2015).

These all cover important parts of MS&E but cannot act as integrating tools for general materials teaching. A previous small survey of actual needs and priorities for MS&E databases among teaching professors (Fredriksson, 2015) can be useful for guidance.

Survey of Needs and Priorities

Table 3. Outcome of survey concerning critical preferences of data tables in EduPack (n=10)

3. Considering your needs and competition with alternative tools on the market (critically), would data tables on the following properties be valuable to you?

Alternatives explained:

Yes=Valuable, or **No**=Not valuable enough (no need/added value)

	[*frequency*]	
Suggested Data Tables for a Level 2 Database	***Yes***	***No***
1 Microstructure Processing Data Table (heat treatments etc.)	[10]	[ ]
2 Materials Characterization and Testing (SEM, Tensile testing, etc.)	[6]	[2]
3 Micrograph Images Data Table (Optical/SEM etc.)	[10]	[ ]
4 Phase Diagram Data Table (Binary alloys)	[7]	[2]
5 Crystal Structure Data Table (Images etc.)	[6]	[3]
6 Functional materials in the MaterialUniverse (piezoelectric etc.)	[7]	[3]
7 Nanomaterials Data Table (1D, 2D, 3D etc.)	[5]	[3]
8 Material Failure Data Table (Case Studies etc.)	[7]	[1]
9 Your own suggestion: ***Thermodynamic Data, Case studies on manufacturing progress ratio***		

We conclude from this (non-comprehensive) background research that, although large databases of ***phase diagrams*** and ***micrographs*** are available, these are focused on research and are likely to be overwhelming to students rather than engaging. A resource that connects the two together and provided a sensible journey/narrative through the material by way of ***microstructure processing***, such as heat treatments, is still needed. Data on ***material properties***, such as the functional materials, were also found desirable.

Results

The Existing Software Platform

The methodology for (linked) materials and process selection was originally developed to support the basic steps in the technical design process, suitable for engineers. It is implemented in the CES EduPack platform and it is described extensively elsewhere (Ashby, 2016). The tools available, to store, find, display, compare, link and use materials data work equally well with other types of data; indeed, they have been used to create databases as widely diverse as French wines, Sustainable Development and Garden plants.

The structural hierarchy of the software is shown schematically in Figure 3. It is based on a set of high quality *Data tables* that are maintained and expanded in a way that is not reliant on academic funding for long-term stability. The second tier, *Visualization* (the ability to make property *Charts*) is part of the software framework and provides opportunities for better understanding of data. New advanced and interactive software *Tools* enable material selection and Eco Audits (streamlined environmental life-cycle investigations). Projects based on the use of the software meet many of the assessment criteria of ABET accreditation and the CDIO Syllabus.

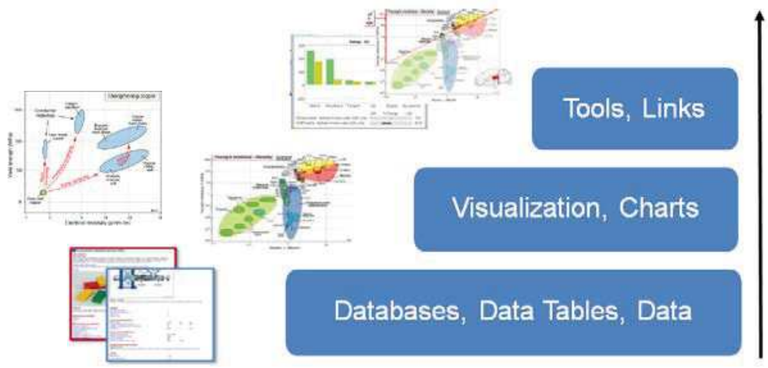

Figure 3: Structural hierarchy of the software: Data as the basis, Visualization to enhance understanding and Tools or Links to make decisions in creative tasks, such as design

The Materials Science and Engineering Extension

Based in part on the work described in the *Background and Methodology* section above, we have developed a prototype add-on database to support the teaching of MS&E, schematically illustrated by the tetrahedral icon at the centre of Figure 4. The database contains a set of linked data-tables (outer ring of Figure 4) that connect key information and concepts from the atomic to engineering scale, from processing to performance, and from science to application, spanning the spectrum displayed in Figure 2. These concepts were all identified in the survey as being of underlying importance in the teaching of MS&E. Some data-tables are expanded versions of those already found in the basic (Level 2) database of the software; others are unique to the MS&E Package.

The **Materials** and **Processes** data-tables lie at the heart of the set. The first contains data records for the properties of structural, functional and biological materials. The second gives access to data records for shaping, joining and finishing processes, with schematics and images of processes. The **Elements** data-table contains data records for the basic properties of the elements of the Periodic Table; they are linked, where appropriate, to records in the other tables giving one-click access to relevant fundamental atomic properties. The **Phase Diagrams** data-table contains 14 of the most common binary phase diagrams. The **Process-Property Profiles** data-table allows the effect of processing on properties to be explored and the associated **Structure and Mechanism Notes** give insight into structural changes that are used to manipulate properties.

The Homepage (Figure 4), acts as an interactive portal to the data-tables and the associated student resources and tools.

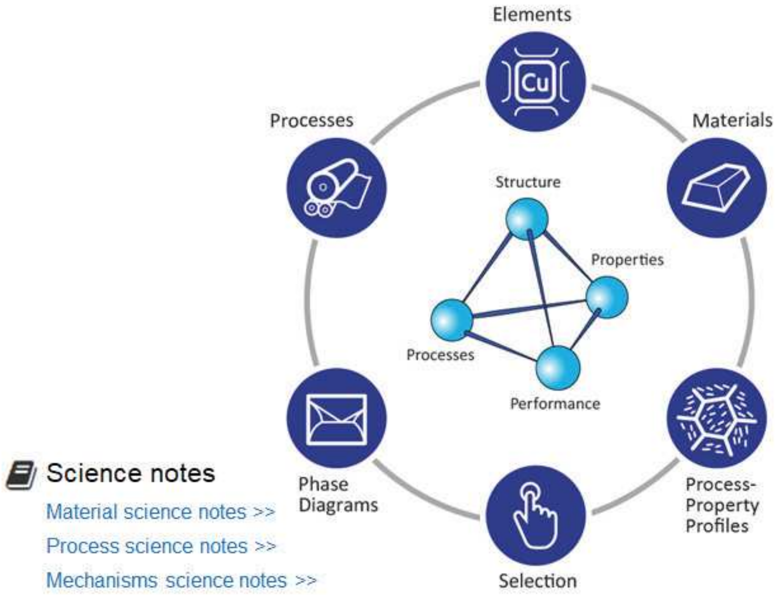

Figure 4: The data-structure of the MS&E database. This schematic appears as the Home Page of the database. Clicking on any one of the six icons activates that component of the database

The content, in more detail, takes the following form:

The **Elements data-table** provides fundamental data about the elements of the Periodic Table: nuclear, electronic, atomic and crystallographic data, and mechanical and thermal properties, environmental characteristics as well as global geo-economic and criticality standing. It is linked to the other data-tables giving direct access from their records to the relevant element-records.

The **Materials data-table** has the same format as the Level 2 Materials database, with two major expansions. They are:

- Records for **functional materials**, including magnetic, magneto-caloric, piezo/pyro/ferroelectric, semiconducting and thermoelectric materials.
- Records and data for **biological materials**, including molecular building blocks, natural fibres, tissues (both soft and mineralized), woods and wood-like materials.

The **Process data-table** contains records for 109 shaping, joining and surface treatment processes with schematics and images of the processes as well as their data and text descriptions. For engineers, a cost model allows the costs of alternative processes to be compared. Links between Materials and Processes allow selection of materials by their processing options and vice-versa.

The **Phase Diagram data-table** gives access to phase diagrams for 14 of the most widely used engineering alloys. There is also a tool to explore microstructures of selected phases.

The **Process-Property Profiles data-table** illustrates control of properties by processing. It contains seven sets of records chosen to illustrate how processes such as alloying, heat treatment, mechanical working, sintering and foaming, change mechanical, thermal and electrical properties. These can be visualized in trajectory charts.

Comprehensive sets of **Science Notes** are accessed from the Home Page (Figure 4, bottom left). They give background to material properties, to processes attributes, and to the mechanisms that underlie properties and the way processes change them.

Summary and Conclusions

As outlined above, we have used initial research and feedback to create a prototype add-on structure for a potential Material Science and Engineering teaching resource based on CES EduPack. This database combines information on microstructure processing, binary phase diagrams and Functional- and Nanomaterials added to the existing data on engineering structural materials and processes in the software. It takes advantage of the interactive and visual information, and the linking of data tables, already available in the software.

The database is already a working prototype, but the tools could be further developed and improved, for example, an extended phase diagram tool or processing-property visualizer, to name a couple of possibilities, with details still to be determined from user feed-back.

In conclusion, the authors hope that this paper and subsequent interaction, will give us the opportunity to better understand Materials Science and Engineering teaching in Universities, what resources are already in current use and what new resources would be most valued. Our next step is to encourage people to give feedback and comments on our new resources. This can be contributed at: http://teachingresources.grantadesign.com/databases-development-ongoing/material-science where also the latest development of this database is posted.

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Retention in the School of Engineering of the Universidad Pontificia Bolivariana, Medellín-Colombia

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CONTEXT This article shares the experience of a persistence (student retention) program articulated with the Academic Advisory of the School of Engineering in the Pontifical Bolivarian University (UPB) - Medellín, through the case study "Ser Pilo Paga", including the educational lag of those favored by the program and the main strategies to mitigate it.

PURPOSE Identify the main factors leading to dropout in engineering students.

APPROACH Documentation regarding the main influential factors for dropouts in Colombia and worldwide, and strategies to mitigate it in the UPB.

RESULTS Articulating the different efforts made in higher education institutions to control lag and dropout is fundamental. Likewise, success indicators that favor a higher quality in education must be generated. It must be noted that this is the first article regarding the Ser Pilo Paga program in the UPB. This suggests that there is not sufficient data concerning students nor strategy results. These will be showed in a second version of this paper.

CONCLUSIONS Efforts must be made answering the different problems that lead to student dropout and lag, so that they are not merely regarded as academical, but rather multidimensional issues.

KEYWORDS Dropout; Student retention; higher education; attrition.

Introduction

According to statistics from the Ministry of National Education (MEN), approximately half of the students entering a higher education institution fail to complete their academic cycle and obtain their degree (MEN, 2009). According to statistics provided by the System for the Prevention of Higher Education Dropout (SPADIES), 48.47% of students who entered higher education in the first half of 2000 did not reach the 10th semester, and neither did 57.2% of those who entered during the first half of 2008 (SPADIES, 2014). Sultana, Khan & Abbas (2017) argue that, even in the most developed European countries, engineering students drop out at a rate of 40% to 50% during their first year, and they may even reach 80% in some engineering disciplines. Paura & Arhipova (2016) studied the reasons for dropout in the Latvian Agriculture University and found similar rates in engineering faculties between 2012 and 2014 (47.6%). Parkin & Baldwin's (2009) results are much lower than those typically found, ranging between 10% and 20% of higher education students who fail to obtain their degree. Generally, Engineering, Architecture and Fine Arts have the highest attrition rates, reaching 50%. Engineering programs show high dropout rates both in Latin America and Colombia (MEN, 2009).

The School of Engineering of the Pontifical Bolivarian University (UPB) - Medellín created a new project called "Academic Advisory" in 2015 as a result of the massive enrollment of students in that year. It was based on a National Government strategy (Ser Pilo Paga) which sought to give access to high-quality higher education institutions to high performing students with scarce economic resources. From that historical moment, different strategies - academic, socioeconomic, institutional, etc.- have been set forth to accompany students.

This article presents a particularity in higher education since the government's initiative, the program "Ser Pilo Paga", and its implementation through the Student Retention Program and Academic Advisory of the School of Engineering for the mitigation of lag and student dropout at the UPB.

LITERATURE REVISION

Both national and international literature was reviewed, since college student dropout is a concern in Latin America as well as worldwide.

Several authors define student dropout as the definitive abandonment of the institution after interrupting studies for two consecutive periods. Changing programs within the institution cannot be considered as dropping out, as these are simple cases of intra-institutional mobility (SPADIES, 2014; MEN, 2009).

Among the main factors identified in the literature as determining for student dropout are individual, institutional, socioeconomic and academic factors.

Individual Factors

Individual factors are related to essential elements such as the career choice (influenced in many cases by family environment, social groups, social prestige of certain professions, etc.), the student's analysis of his or her university life, the individual's perspective on a chosen career, expectations of success, failure intolerance, sex (dropout risk decreases in female groups), age, and others (Fishbein & Ajzen (1975); Attinasi (1986); Ethingon (1990); Franco (1991), cited by SPADIES (2014); Castaño et al., 2004; MEN, 2009; SPADIES (2014)).

Institutional Factors

Different authors confirm the importance of student integration to campus life and their accompaniment in different processes. Academic records -such as previous academic performance and the institution attended- are relevant to attrition rates. Students who studied in private schools seem to be less likely to drop out. Institution commitment in student training is key since the beginning of the programs in order to create a sense of belonging and integrate the student in their environment. Welfare programs are also considered as an influential factor in student dropout (Ethingon (1990); Spady, 1970; Tinto, 1975; Cabrera, Nora & Castañeda, (1993); Gresia, Porto & Ripani (2002)).

Academic Factors

Several authors confirm that students drop out more frequently during the first semesters of their career. This is affected by their academic performance in high school, academic integration and academic performance in general when entering college. Interaction with teachers and other students is also important, as it has been verified that those who interact more have a lower risk of dropping out. Among the academic factors that increase the risk of dropping out, it is possible to identify flexible curricula, pedagogical modalities, repetition rate, learning styles, time management, and others (Bank, Slavings, & Biddle,(1990); Castaño et al., (2004); MEN, (2009); SPADIES, (2014); Sultana, Khan & Abbas (2017); Sittichai, (2012); Acevedo, Torres & Tirado, (2015); Paura & Archipova, (2016); Iam-On & Boongoen (2017)).

Socioeconomic Factors

The literature points to socioeconomic factors such as: parents' educational level, for the higher the parents' education is, there appears to be a lower dropout risk for the student; family income, for a lower income represents a higher dropout risk; work, for students who have jobs have a higher dropout risk; career preference, for being enrolled in a program that is not of their preference creates a higher dropout risk; adaptation to the institution regarding personal socio-economic situation; among others (Acevedo, Torres & Tirado, (2015); Sittichai, (2012); Ministerio de Educación, (2009); SPADIES, (2014)).

Furthermore, these factors and dropout per se affect the institution's reputation, as well as the relationship of families with institutions, not to mention that national economic inequalities may increase (Raviv & Bar-Am (2014); MEN, (2009); Castaño et al., (2004)).

Methodology

The main objective of this article was to share the experience gathered from the Student Retention Program from the UPB - Medellín in the School of Engineering and revise similar experiences nationally and internationally, through:

- Reviewing literature on the main causes worldwide for student dropout and strategies to mitigate it
- Documenting the Student Retention Program in the UPB, considering its evolution in the institution and the articulation with the School of Engineering for the mitigation of student dropout with its different programs
- Identifying the root causes of student dropout
- Determining strategies for the mitigation of student dropout

Student Retention Program in the Pontifical Bolivarian University (UPB) - Medellín

The Student Retention Program in the UPB - Medellín, its evolution, support team, strategies, and the particular case of dropout management at the School of Engineering are presented below.

Description of the Student Retention Program in the UPB - Medellín

The Student Retention Program in the UPB - Medellín first started in specific areas. By the year 2010, a group that began to think about the persistence of good students in a centralized way was created. In 2015, the program became official and was led by the Pastoral Vice-Ministry. Finally, it became part of the Academic Vice-Ministry in 2016.

The program aims to strengthen the integral accompaniment of undergraduate students through the implementation of strategies that increase their persistence and success. Some of the subprocesses that are managed from the Student Retention Program in the UPB are: i) school-university articulation, through integrated curricula, academic internships, professional orientation, among others; ii) adjustment to university life, with psycho-pedagogical, psychosocial and economic support; iii) preparation for professional life; and iv) return to the UPB.

Student retention or persistence is understood as the scenario that shows the decision of the college student to carry out the program offered by the university, favored by institutional, academic, psychosocial and economic conditions. In these conditions, multiple opportunities of accompaniment to the student have been detected, given the high risk factor that they represent in student dropout as it was observed in the literature review.

Some of the strategies generated in the face of risk factors for the community in general are shown in Table 1.

Table 1. Strategies according to risk factors

Risk factor	Strategy
Academic	Professional orientation Intervention in most failed or dropped-out courses Academic follow-up Workshops for learning, psycho-pedagogical accompaniment, others

Psychosocial	Psychological and spiritual counseling Programs for the detection and management of mental health risk factors in the university community Programs to strengthen the student's abilities and resources in their training process
Economic	Solidary supports (food, transport, photocopies, materials) Follow-up and orientation in scholarships and discounts Case analysis of calamitous situations for financial aid and others
Institutional	Strengthening and positioning of retention program Improvement of the quality of data related to information on attrition and institutional persistence Articulate work among areas related to students

Source: Own elaboration.

"Ser Pilo Paga" Program

The "Ser Pilo Paga" program was conceived when a doctoral thesis confirmed that, in Colombia, around 17,000 youths of strata 1, 2 and 3 with excellent results in the Saber 11º tests, but with low economic resources, could not access high-quality higher education. Based on this analysis and within the "Agreement for the Superior 2034" framework, the National Government announced the "Ser Pilo Paga" program in order to give these young people from different regions of the national territory access to accredited universities, seeking to narrow educational gaps (http://aprende.colombiaaprende.edu.co/es/pilopaga/91610):

This program grants 100% subsidized credits. The condition for acquiring them is the graduation of the student from the academic program in which he or she was approved. The requirements to apply to this program are the following (http://aprende.colombiaaprende.edu.co/es/pilopaga/91610):

• Being Colombian

• Having a score in the Saber 11º test equal or higher to: 310 (Ser Pilo Paga 1); 318 (Being Pilo Paga 2); 342 (Ser Pilo Paga 3)

• Having attended and approved the 11th grade during call year (this only applies only for SPP 2 and SPP 3)

• Being admitted to an academic program, in face-to-face mode, offered at a higher education institution with high-quality accreditation (or in the process of renewing accreditation)

• Being registered in the Sisbén database within the due date and with the score established in each of the calls. In the case of being indigenous, students must be in the Ministry of the Interior database within time frames established by each call.

Each call has different regulations. However, some remain the same, such as receiving 100% subsidized credit if the degree is obtained in the expected time, having the right to two postponements periods throughout the career, having at least one transfer opportunity with due justification, among others.

Ser Pilo Paga in the Pontifical Bolivarian University (UPB) - Medellín

Since the Pontifical Bolivarian University is one of the most prestigious accredited universities in the country, when this government program was started in 2015 there was an income of approximately 600 "Pilos". In 2016, there were 650 and, in 2017, 400. As much as 51% of them chose the different programs offered in the School of Engineering (Aeronautics, Industrial, Administrative, Chemical, Mechanical, Electrical, Electronics, Agroindustrial, Textile, Nanotechnology, Telecommunications, Design of Digital Entertainment, and Systems and Computing). The UPB was the higher education institution most requested by the beneficiaries of the program in Antioquia.

The scenario was quite positive as it fulfilled its main objective, yet some neuralgic points to be adjusted were identified in order to better achieve goals as well as mitigate dropout rates:

• Program selection without previously reviewing said program

• Difficulties adjusting to the city

• Failure intolerance

• Admission to college at an early age

• Issues with basic skills such as reading comprehension

• Economic conditions that limit the training process of some favored students

• Basic competences in mathematics

The University and, especially, the School of Engineering have generated strategies to accompany students in their training process, e.g. the creation and strengthening of the Student Retention Program for the entire university, and the Academic Advisory from the School of Engineering, directly articulated with the Student Retention Program, and through which the different School strategies are intended to be managed.

The aforementioned factors have been mitigated as much as possible with the program, which is the central axis for the accompaniment and follow-up of all those activities in favor of the student, as well as with College Wellfare through psychological and economic support programs (such as food aid and transport aid), and time management and study technique workshops, and the Academic Advisory through direct counseling in the management of the curriculum and redirecting, whenever it is considered pertinent.

Several accompanying strategies have been implemented prior to the Student Retention Program and the Academic Advisory in the School of Engineering, both in the area and the physics center, since 2008. One of the most successful projects within students was the creation and ideation of "useless machines”, also known as "Goldemberg Machines”, with which students develop research skills and understand physics in a more dynamic way. Similarly, as an initiative of some science teachers, the Academic Action and Intervention Group (GAIA) was created. It aims to provide accompanying resources, strengthen and generate basic mathematical skills, specially for those students diagnosed with particular difficulties for understanding concepts or mathematical algorithms. It helps them acquire basic skills that improve their academic performance through personalized attention (López, Cardozo, Posada, & Cano, 2015).

Through the joint efforts of the Student Retention Program and the Academic Advisory of the School of Engineering, dropout risk factors, not too different from those found in the literature, were identified and can be classified in four major groups: individual, socioeconomic, academic and institutional.

The case of the "Ser Pilo Paga" Program is presented and the opportunities it has provided to the institution in the analysis of student dropout and lag. As previously stated, the School of Engineering has received approximately 51% of the "Pilos" who have entered the institution since the year 2015.

22% of the students that joined the university since 2015 have dropped out, while 50% of them have lagged behind. The students who attended the meetings convened in October of this year, which were 50% of those invited, expressed that the main reasons for academic lag are inadequate study methods, low previous academic competences, time management difficulties, low motivation and academic commitment, academic stress, and others.

The student dropout rate in the "Ser Pilo Paga" Program does not correspond to the numbers typically found in literature. Possibly due to the nature of the program, students focus on completing their degrees in order to cancel 100% of the credit. Nevertheless, lag percentage is higher than 50%. Students who started in 2015 and 2016 have a delay of two to four semesters. The main weaknesses within the academic factor were: lack of previous knowledge, critical readings and, in addition, lack of student motivation. As a consequence, there was considerable difficulty in overcoming the basic sciences. Table 2 shows the courses that are most repeated.

Table 2. Most repeated courses

Course Department	Course
CENTER FOR BASIC SCIENCES	Differential calculus
	Analytic geometry
	Integral calculus
	Linear algebra
	Mechanic physics
	Basic mathematics
	Humanism and citizen culture
	Electricity and magnetism

	Geometry and trigonometry
	Basic chemistry and laboratory
	Engineering drawing
	Vector calculation
	Vector geometry
	Differential equations
	Mechanical and lab foundations
	Discrete mathematics
CHEMICAL ENGINEERING	Statistics and experi design
	Chemistry fundamentals
CENTER FOR HUMANITIES	General ethics
	Basic christology
LANGUAGE AND CULTURE	Language and culture (education)

Source: Own elaboration.

It is important to note that, from the courses shown in Table 2, approximately 76% of them are basic sciences. From this percentage, 32% of the courses belong to the first semester (Differential Calculus and Analytical Geometry), 24% to the second semester (Integral Calculus and Linear Algebra), and 7% to the third semester (Vector Calculus and Differential Equations). That is, approximately 63% of most failed basic science courses take place within the first three semesters of an engineer's training career. This fact corroborated what existing literature shows.

Analysis carried out by the System for Dropout Prevention in Higher Education (SPADIES) have identified the first four semesters as the period with the highest dropout numbers. In the case of Colombia, the main factors associated with this phenomenon are related to low academic entry skills, economic difficulties and aspects related to socio-occupational orientation and adjustment to the university environment (MEN, 2015).

Academic preparation is one of the most powerful predictors of student persistence in higher education. Low-quality secondary schools that tend disadvantaged populations fail to properly prepare youths for higher level education challenges. Therefore, they are unlikely to earn an undergraduate degree. Educational initiatives that seek to compensate this aim to increase the amount of students that can enter and remain in higher education systems (Savitz-Romer et al., 2010). Although this is ideal, it is important to consider the issue of inclusion and understand attrition in a holistic way. Therefore, from the School of Engineering through the Academic Advisory and in articulation with the University's Student

Retention Program, some strategies have been proposed to mitigate lag and possible dropout of the "Pilos" (Table 3).

Table 3. Risk factors and strategies to mitigate student lag and dropout.

RISK FACTORS	Strategy to mitigate lag and dropout
Low access to vocational guidance processes since middle school: students' vocational choice is mainly guided by a teacher or a family member, according to the skills they saw in them	Provide vocational guidance tests online at the UPB Portal for students interested in entering the institution
	Carry out a Vocational Orientation process for all potential beneficiaries of the "Ser Pilo Paga" program who will join the UPB
Students with conceptual gaps since middle school: 85% of students report academic difficulties (basic science)	Perform a diagnostic and leveling process in critical reading and basic math for all students entering the University. This strategy was designed for the School of Engineering in the first three semesters, offering courses with the basic knowledge required to tackle the corresponding courses at each level.
	Strengthen academic accompaniment strategies (Monitoring, Tutoring, GAIA, Academic Support to Student, among others)
Adaptation difficulties: Some students come from municipalities or neighborhoods that have very different cultures and social dynamics from those experienced in the city of Medellin. Likewise, many young people have spent their whole lives with their families and when they move from remote regions, they must learn to live alone and take on new responsibilities, i.e. money management	Broaden guidance day objectives in order to include informative strategies regarding campus and city life and facilitate the adjustment of new students and, especially, foreigners: they will become more familiar to college early on and, thus, favor their adaptation and the search for timely support.
	Provide information about access routes, transportation, nearby neighborhoods where they can look for student residences, among other important issues regarding the city since the admission

Source: Own elaboration.

Most of the strategies proposed above correspond to the Prevention Phase, during which the UPB - Medellín and, in general, the Colombian educational system must strengthen processes of articulation between schools and universities, and emphasize strategies of academic and integral growth during the First Year. According to the literature, this is the key point to prevent dropout and promote persistence and successful egresses.

The financial investment in these strategies is compensated by the persistence of each student, for having to invest in remedial strategies or late intervention in students who drop out is more expensive.

Finally, it is important to note that this article is the first documentation of the “Ser Pilo Paga” Program in the UPB. This implies that there is no sufficient data regarding students nor strategy results. These will be addressed in a following version of this research.

CONCLUSIONS

The main reasons behind student lag mentioned by students that belong to the “Ser Pilo, Paga” Program in the UPB were: inadequate study methods, low previous academic competences, time management difficulties, low motivation and academic commitment, stress, adjustment difficulties, economic hardship, among others.

Efforts must be made answering the different problems that lead to student dropout and lag, so that they are not merely regarded as academical, but rather multidimensional issues. Some of the efforts that must be considered in the academic factor are leveling courses, transition programs, monitoring, tutoring, support courses in different modalities and the use of different teaching and learning methodologies.

Continuing programs, academic counseling, and other support schemes in student training should join efforts in order to provide better student orientation. Individual efforts have been registered as failing to achieve the goal and rather losing resources. Furthermore, it is key that the actions are preventive and planned according to each context.

Institutions of higher education must work on strategies to create a sense of belonging in students, since it has been proved as a key element in persistence.

It is important that universities design student retention success indicators, without compromising their standards.

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Integrated Engineering – Implementation and Transition

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C1: Integration of theory and practice in the learning and teaching process.

CONTEXT

Several approaches to improving the student experience and learning outcomes in engineering education have been proposed, including active learning (e.g. flipped classrooms), project-based learning, problem-based learning (PBL), peer-assisted learning (classroom or project-based), peer convening, etc. Some of these approaches have been shown to be very effective at motivating student learning, whilst also developing generic skills (e.g. communication, teamwork) and professional engineering skills (e.g. design, project management).

However, there are some trade-offs, e.g. the latter approaches are often either fragmented in their introduction, or are accompanied by a complete overhaul of the curriculum. It is also often not clear how to effectively mix different forms of pedagogy in an integrated curriculum, nor how to transition a curriculum to incorporate new forms of pedagogy without disruption.

PURPOSE

This paper proposes a curriculum framework with a significant proportion of problem-based and peer-assisted learning within an otherwise ‘traditional’ engineering curriculum. The aim of the framework is to provide a practical transition pathway for substantially increasing the proportion of project-based and peer-assisted learning into an established engineering program without major disruption.

APPROACH

The proposed framework is an extension of the ‘Macquarie model’ of engineering curriculum, in which core technical units sit around a spine of professional development units. The key innovation is the proposed restructuring of the program from a single spine to an array of “pillars”, including a pillar of non-discipline-specific project-based units designed to develop both technical and professional competencies and facilitate peer-assisted learning between students with different specialisations or majors and at different stages of their studies. This will allow the introduction a substantial proportion of project-based and peer assisted learning, and future evolution of the curriculum with minimal disruption.

RESULTS

An integrated curriculum for undergraduate engineering education is proposed that we believe combines the best aspects of a ‘traditional’ engineering curriculum with project-based and peer-assisted approaches to learning, whilst also providing a practical pathway for transition to engaging methods of pedagogy within existing curriculum frameworks.

CONCLUSIONS

We propose an integrated model of engineering curriculum design based on ‘pillars’ that combines a range of learning approaches, linked as appropriate for the development of contextual and professional and technical knowledge and skills. The framework should also facilitate future evolution of the engineering curriculum, and the development of the broad range of competencies needed by modern engineers.

KEYWORDS

Curriculum, project-based learning, peer-assisted learning, multidisciplinary engineering.

Introduction

Instructional system design is a longstanding but nevertheless dynamic area of research. One of the drivers of change has been new technology (e.g. social media, computation and visualisation tools, virtual environments), which opens new ways for students to engage with their teachers, their peers, and the core knowledge and concepts with which they are expected to become familiar during their studies (Facer & Sandford, 2010). Other drivers include changing demands and expectations within the profession and broader society (Froyd, Wankat, & Smith, 2012).

A fundamental aspect of instructional design that continues to focus the attention of educators is the interrelationship between theory and practice in education, especially in the professional disciplines, such as engineering. Which comes first; theory or practice, understanding or competency? These are perennial questions which probably have no definitive answer – like wave-particle duality of light, it depends on the situation as to whether theory or practice may be more important, nevertheless both are equally necessary in engineering and their development should be integrated. (Alias, Lashari, Akasah, & Kesot, 2014)

To some extent the tension between theory and practice in engineering derives from how engineering has evolved over the last century or more, i.e. from a primarily practice-based 'art' learnt on the job, to one built on fundamental understandings of nature derived from mathematics and basic sciences. (Froyd et al., 2012) More recently, curriculum design and learning activities have evolved in response to an increased demand by stakeholders for the development of generic skills and attributes in graduates (including engineering), such as teamwork, communication, ability to self-learn, and also professional engineering skills and competencies (more specific to engineering), such as design, systems thinking, practical ability, project management, ethical behaviour and leadership (Moore & Voltmer, 2003). This has focused attention on approaches to developing both generic and professional engineering skills and competencies, at least within specific units (G. E. Town & Mcgill, 2008), and to the particular challenges in doing so in very large cohorts of students. (Schröder, Janßen, Leisten, Vossen, & Isenhardt, 2013)

A related and equally important question is then; how can we best structure a program of learning that properly balances the fundamental elements of engineering training, and furthermore, how best to implement such as program within the constraints of an existing curriculum framework and an evolving tertiary education system? A strategic framework of modern engineering education providing integrated development of relevant skills and knowledge has been proposed, based on three pillars of science, design and commercialisation (Quayle, 2010).

In this work we briefly review the approaches taken to date for integrating theory with practice, and technical with professional competencies in engineering curricula, and then propose a curriculum framework similar to that proposed by Quayle (Quayle, 2010), but instead integrating the following four 'pillars' in a 4-year engineering degree program;

i) specialist technical knowledge and skills,
ii) professional and generic skills,
iii) multi-year cross-disciplinary projects,
iv) contextual knowledge and electives outside engineering.

We believe the latter framework will facilitate a staged transition with minimal disruption from a 'traditional' engineering curriculum (Johnson, Ulseth, Smith, & Fox, 2015; Prasad, 2011) to a curriculum providing more balanced integration of theory with practice, technical with professional skills development, and specialist engineering with contextual knowledge, as has been argued is necessary to prepare future engineers for professional practice (Barakat, 2014; Buelin, J., Clark, A. C., Ernst, 2016; Cheville & Bunting, 2010; Director, Khosla, Rohrer, & Rutenbar, 1995; Pratley & Whitty, 2007; Quayle, 2010).

Furthermore, a broad-based engineering curriculum designed to train 'Renaissance engineers' will better prepare students for an ever-changing and increasingly complex world (Akay, 2003; Moore & Voltmer, 2003; Rainey, 2002) and is also likely to benefit society by attracting a wider diversity of students and preparing them for positions of responsibility.

Curriculum design

In learning, as in everything else we do, there is no doubt that *how* we learn has a large impact on *what* we learn, and that the best learning occurs when there is constructive alignment between learning outcomes, activities and assessment, as elucidated by Biggs (Biggs, 2012, 2014). The focus on the student and learning outcomes is consistent with systems approaches to education in designing learning programs (Godfrey, P.; Crick, R. Deakin; Huang, 2014; Rompelman & De Graaff, 2006).

It has long been recognised that engineering students require practical learning experiences, and consequently in most engineering programs i) laboratory classes are used to support the assimilation of theoretical concepts, ii) a 'capstone' project unit must be completed in which engineering skills are applied to a real problem, and iii) a minimum amount of industry experience must be accumulated before graduation. With some notable exceptions, the industry experience is usually not embedded in the curriculum, and often is not well managed, and hence the benefits are highly variable.

More generally, the links between content, process, and outcomes in learning have motivated the development of a variety of approaches to what may generally be described as 'learning in action', ranging in scope from the relatively narrow active learning in the classroom (Lage, M.J., Platt, G.J., Treglia, 2000; Zuber, 2016), to more wholistic approaches requiring deeper and more prolonged student engagement throughout entire units and programs of study (Biggs, 2012; Frank, Lavy, & Elata, 2003; Johnson et al., 2015; Kanigolla, 2013; Mills, J. E., and Treagust, 2003; Perrenet, Bouhuijs, & Smits, 2000; Prasad, 2011), including immersive engineering (Blashki, Nichol, Jia, & Prompramote, 2007).

The latter approaches aim to provide relatively open learning experiences which can integrate the development of technical, practical and professional competences. They can also assist learning by increasing student motivation, through projects with real and useful outcomes beyond the learning process, and possibly outside the formal learning environment, e.g. as in Engineers Without Borders (Wittig, 2013).

Taking the learning in action approach further and shifting to a completely project-based learning program would often require a complete overhaul of the engineering curriculum. The engineering program offered by Olin College is an early, notable, and successful example of this, in which the educators had substantial financial support and the rare opportunity to develop a largely project-based curriculum from the beginning with clear goals in mind (Guizzo, 2006; Somerville et al., 2005).

However, for a variety of reasons most engineering schools would find It difficult to undergo such a radical transformation, and would instead prefer to evolve their curricula and avoid major upheavals. Access to limited resources (e.g. learning spaces), dependence upon service units, university rules and regulations, may all work against radical curriculum changes. Which raises the question, is there a curriculum structure that would facilitate evolution, or continuous improvement of the curriculum, rather than a more radical approach to curriculum development?

Proposed Curriculum Framework

The curriculum framework shown in Figure 1 below is proposed to i) introduce a well-defined stream of problem and project-based learning into the curriculum, and ii) to reduce the amount of technical engineering content (i.e. from 90% to 75%) and add breadth by allowing an increased number of 'non-engineering' units, all with minimal disruption to existing programs.

Specifically, the changes are designed to introduce a new and structured PBL experience, and the benefits this mode of learning has been shown to bring, especially in engineering (Alias et al., 2014; Johnson et al., 2015; Mills, J. E., and Treagust, 2003; Perrenet et al., 2000; Somerville et al., 2005; Wittig, 2013). The framework is also intended to facilitate staged development of specific areas of competency (e.g. professional skills) throughout the 4 year engineering program.

Table 1: Proposed engineering curriculum based on 'pillars'

Foundation units 12.5% **+** **Minor units 12.5%** **+** **Context units 12.5%**	**Professional units 12.5%** Generic and professional skill development. *(Current 'spine')*	**PBL units 12.5%** Cross-year, multi-disciplinary projects. *(Proposed new 'pillar'.)*	**Technical units 12.5%** **+** **Technical major 12.5%** **+** **Final year project 12.5%**
MATH, PHYS COMP, etc.	**ENGG100** Generic	**ENGG150**	
MATH, PHYS, COMP, etc.	**ENGG200** Design	**ENGG250**	
ELECTIVES	**ENGG300** Research	**ENGG350**	
ELECTIVES	**ENGG400** Systems	**ENGG450**	

The above framework may be regarded as an extension of the 'Macquarie model' of engineering curriculum, in which a 'spine' of professional units (ENGG100 - ENGG400) runs throughout the 4 year program, the aim of which was and is to address a need for professional development content in a program which, at least initially, was heavily loaded with Science units. These units have been evolving end becoming more coherent over time, with the general aim to progressively develop a hierarchy of professional skills throughout the program, e.g. teamwork and communication (ENGG100 – ENGG400), design (ENGG200-ENGG400), self-learning (ENGG300 - ENGG400), and systems thinking (ENGG400).

The curriculum structure naturally lends itself to the introduction of a second 'spine' or 'pillar' of problem and project-based learning units (ENGG150-450), one per year. The introduction of a PBL-pillar will require a 10% reduction in the number of technical lecture-style units, however we believe this will be more than compensated by the benefits of engaging students in multi-year and multi-disciplinary project-based units, such as has recently been trialled (G. Town & Tse, 2016).

A similar curriculum model structured as 'pillars', was recently proposed by Quayle (Quayle, 2010), however in that case the pillars targeted distinct discipline areas (i.e. science, engineering design, and commercialisation, respectively). We have adopted a similar approach, but grouped skills development into pillars by type (practical, theoretical, technical, professional, etc.) in which the development of the associated skills and competencies can be more deliberately staged (as in ENGG100-ENGG400). Coordination between pillars would also be required in a properly integrated curriculum.

The advantages of the pillars, each extending throughout the 4 year program as shown schematically in Figure 1, are as follows;

i) allows introduction of a distinct 'pillar' of project-based learning activities engaging students across all 4 years in multidisciplinary projects,
ii) better accommodates a range of learning styles and interests by providing mix of classroom and project-based learning activities,
iii) sets aside clear space for broader contextual content (e.g. elective and minor units),
iv) provides a clear balance between technical and non-technical content, and between foundational science versus engineering content, etc.

Another advantage of the structure is that any pillar may be developed and revised from beginning to end without significant disruption to the other pillars in the program, facilitating coordinated and sustained development of the associated competencies.

Conclusion

An engineering curriculum framework has been proposed which incorporates distinct but connected streams (or pillars) focused on staged development of specific groups of competencies within an engineering program. The framework provides a number of advantages, including facilitating staged development and improvement of particular classes of skills (e.g. generic and technical), and the ability to overhaul or introduce new pillars into an established curriculum with minimal disruption (e.g. such as a dedicated project-based learning pillar). In a truly integrated curriculum the learning progress in each pillar would need to be coordinated, i.e. to utilise and reinforce the learning outcomes occurring in other pillars. The approach proposed here sees coordination across pillars as a secondary rather than primary task in curriculum design, and consequently is different to most current practice in which curricula are primarily built and structured around years of study.

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